NUCLEAR ENGINEERING VOL. 5 NO. 48 MAY, 1960

Development With Limited Resources

AN examination of the power situation and development programmes in such countries as Sweden and Finland (pp. 199-206) throws into relief the dilemma in which smaller nations can find themselves. Facing a widening gap between indigenous energy supplies and home demand yet feeling compelled to minimize their dependence upon outside suppliers, they must decide to what extent their power programmes should be based upon their own development experiences, constructional capacity and supplies of raw material, how large national pride should figure in the adoption of a particular generation complex, to what extent should cost per unit sent out dominate the situation and what balance of payments must be maintained.

The compromise solution to these problems and the weighting of the various factors will vary from country to country. The Korean war and the Suez crisis have made all countries wary of relying too heavily upon imported supplies of oil and although the importation of coal in certain cases looks at the present time to be satisfactory few will gamble on the continuation of the present over-production or on the stability of prices over a long period. As the gap widens the balance of payments can be the overriding criterion forcing them back on to their own resources.

Where indigenous supplies of uranium are available then the attractions of nuclear generation are self-evident, even where the reserves are found in low concentrations. Provided the mining and extraction cost is not exorbitant home supplies can be either exploited immediately or, if the foreign currency is available, held in reserve while advantage is taken of the low cost of internationally available fuel.

But from a decision to incorporate a significant fraction of nuclear generation capacity into the overall programme to the setting up of an organization capable of developing an economic reactor system is a very big jump. Sweden is finding that the high cost of development quoted by the more advanced nuclear nations is no idle myth.

Taking as a basic principle that the reactor must be capable of burning natural uranium Sweden embarked upon the development of a heavy water reactor. Canada has, of course, adopted the same principle but did begin with an inherited experience in the construction and operation of these reactors and can more easily afford to delay the start of a large-scale constructional programme.

Even so, the Canadian programme has come in for heavy fire and it has already been expanded to include organic cooling. The United States is pressing ahead with a limited programme of heavy water reactor development but in all the recent evaluations of the potentials of the system the generating cost has shown up unfavourably in comparison with the light water moderated and organic moderated systems. These are based on the use of enriched fuel at American prices but international comparisons of these generating costs with those of the British reactors have shown close parity.

Even if one is sceptical about such cost comparisons there is no avoiding the fact that a great deal of money has been spent upon the development of the systems and that this expenditure is continuing and that the construction programmes at least of the British reactors are backed up by the mass-production facilities which have such a significant influence on the generation cost. The steady reductions in capital cost shown in the tenders to the CEGB give ample proof of the benefits that accrue from concentrated and massive development effort—an effort which would be quite disproportionate in a country with a relatively small industrial output. Even therefore, if the potential of the pressurized heavy water reactor were the same as, say, the gas-cooled graphite moderated reactor, unless the same weight of development effort could be put in, the same generation cost could never be realized.

Furthermore, if the requisite independence of outside supplies—if only in an emergency—is to be met, the country requires to build up its ore-extracting processing techniques, its fuel element manufacture, inspection and testing facilities, its fuel processing plant, its operational research teams—and these alone could absorb the total effort that is available in Sweden at the present time.

This is not to suggest that reactor development should be abandoned in a smaller country as the integration of nuclear power into the country's generation necessitates the building up of expertise—the familiarization of engineers and those responsible for safety with the general and detailed problems, the ability to evaluate the advantages and disadvantages of alternative systems and also industry must be prepared for the job of taking an increasing part in the construction of new stations. This would seem to be the most important objective and the real danger in developing an original system lies in the country's outlook and economy being directed

towards a justification of the chosen system rather than to the acquisition of the necessary experience.

By appropriate collaboration, particularly between home industries and those abroad, full advantage can be taken of the development effort expended in the major nuclear countries and the cost of power can be expected to be less with each new installation and to follow the pattern of world development. With individual approaches, industry will neither have the effort nor the competitive incentive to go on improving continually, mass-production techniques will not be brought into play and much of the time and money that has been expended will be wasted.

Collaboration involves no loss of security as (with a natural uranium system) the whole of the foreign expenditure can be accounted for in the capital cost; there is no long-term dependency problem. Should foreign exchange problems arise the country will be able to fall back on its own raw material supplies with a relatively minor penalty in terms of generating cost. Furthermore, a great deal of even the initial building can still be handled by the home industry.

Paying for Development

IT has been a cause of surprise to some, that in spite of the operation of Calder Hall and Chapelcross and the big developments in the system made by the Groups, the Authority's research and development into the Magnox reactor system should continue to increase. A great deal of this is to support the AEA's own industrial operations, viz., the production of uranium, the manufacture of fuel elements and the reprocessing thereof. The research that led to the development of the fluidized bed process at Springfields is an example of the significant financial gains that can result.

There are, however, areas of research and development where the responsibility is not so clearly defined and where leadership and probably financing by the AEA are still required.

The Groups themselves are concerned with the detailed engineering of the reactors and many of the problems that arise are peculiar to their own designs and their solutions will be the subject of company patents. An example of this is the rattling that has been observed on elements of the type destined for the Bradwell reactor. Heat transfer tests had masked this particular effect which arises from the hydrodynamic action of the gas stream on the fuel elements which are a loose fit in the fuel channels, causing them to vibrate as a mass. There are a number of simple solutions to this problem which do not entail any re-design of the fuel element itself but can be accommodated in the end fittings. The final design adopted by the company is in effect owned by the company and will be employed in the company's proposals for future Magnox reactors. Here the onus of responsibility is clear-cut and it is an investigation which the company undertakes on its own initiative.

At the Berkeley Laboratories the Generating Board is setting up an establishment to undertake research into the operation of gas-cooled reactors. There is considerable economic incentive for this as, particularly with the metallurgical limitations imposed on fuel element life, quite minor variations in operational practice can lead to material economies which, integrated over the life of the Board's reactors, may represent a saving of many millions of pounds. To a certain extent the research at Berkeley will overlap the research undertaken by the AEA aimed at improving fuel element quality and certainly much of the post-irradiation examination work will be complementary. The basis, however, of the CEGB's research is the scheduling of reactor operation to give minimum cost per unit sent out. This is not necessarily the same as increasing the life of the fuel elements in the reactor although the two are interdependent. There are numerous aspects of operation which merit investigation, for example, control rod patterning, the effects of thermal cycling and probably, in the more distant future, fuel shuffling. There is little doubt that the Board's laboratories at Berkeley will be fully extended in examining these problems without any of its effort being devoted towards reactor design. No doubt, information on the fuel element behaviour will be of great assistance to the AEA, and the Board's findings will result in modifications to the design of new reactors, but these will be incidental to the main purpose.

A less clear field of research concerns such problems as the possibility of instability in the heat exchanger banks due to hydrodynamic resonances resulting either in excessive shear forces at the junctions with the shell, or excessive fatigue. Recent experiments in America have indicated that in certain circumstances such instabilities can arise and the question that must be answered is whether these should be investigated before the new power stations are completed. Laboratory experiments are not possible due to the difficulty of scaling, and testing can only be conducted upon full-size S.R.U.s. The Groups do not believe this to be a material problem in relation to their own individual designs. The Generating Board can scarcely be expected to institute of its own accord research into this question as this is not an operational matter so much as a design problem. Yet this is a phenomenon that merits investigation if only possibly to enable negative data to be accumulated to assist the design of future systems. It would not be all that difficult for a circuit to be built at one of the Board's stations, for example Hinkley Point (at Bradwell and Berkeley too great an interruption to the constructional programme would be involved), and for representative banks of elements to be tested. This will not be done, however, unless the AEA is prepared to shoulder the responsibility and to finance the experimental programme. The distinction between such research and the development, say, of materials is purely academic and the expenditure of a small amount today could save the country significant sums in the future.

DIGEST...

Surveying Significant News

Nuclear Installations Licence and Insurance Act Now Law

The Nuclear Installations Act came into force on April 1 and, in accordance with the new law, licences have been granted to AEI for the operation of MERLIN and to Hawker Siddeley for the operation of JASON. In Statutary Instruments No. 514 the interpretation of the term occurrence and how such a one should be reported is defined. Apart from the more obvious accidents resulting in the damage to property or a hazard to people the Minister must be informed when any failure or defect in any part of the plant concerned results in the operation of the plant being forcibly stopped for a period of over one hour. The Ministry will thus be kept continuously aware of even minor breakdowns whether these result from spurious instrumentation trips or genuine reactor faults.

Dungeness Tenders Below £100/kW

Although the final figure will not be determined until negotiations between the CEGB and the successful Group are complete it is understood that both TNPG and the English Electric Group have submitted tenders for Dungeness which are below £100/kW. This is in spite of the difficult civil engineering which has added several pounds per kW to the basic price. (We should apologize for a misprint in the figures quoted last month relating to this aspect.)

IAEA Board Approves Safety Procedures

At its meeting in April the board of the IAEA approved a set of measures to protect and ensure safety in atomic energy operations. States assisted by the Agency will be required to furnish annual reports detailing the exposure of personnel over and above the m.p.l.s; the types, quantities and disposal of radioactive wastes, and will be required to notify the agency within 48 hours of any major incident involving the exposure of personnel to levels of 12 rem or more. Other data can be demanded and the Agency may conduct up to two inspections per year.

Location of SELNI Plant Still in Doubt

Following the protest over the use of a site at La Spezia for SELNI's 160 MW PWR the Trino Vercelles town council has proposed a site within its territory. SELNI has completed a survey of the suggested area and has submitted a preliminary report on safety to the Ministry of Industry, as an alternative to the Vallegrande site which has also been considered. This project has hung fire now for three years but a final decision is expected before the summer.

Brazil to Invite International Bidding

Brazil has decided to seek tenders from all major manufacturing organizations for its 150-MW plant at Pareti rather than British companies only. Kennedy and Donkin have been appointed consultants and are engaged in preparing the invitations to tender. The project (termed the Mambucaba Project) is to be headed by O. A. Dias-Carneiro a member of the National Commission.

Rate of Electricity Consumption Increase Continues to Rise

Statistics released by the Electricity Council show that the annual increase in electricity consumption in the U.K. is at its highest level for more than 10 years when corrected to standard conditions. Over the past 12 months consumption rose by 10.6% as compared with an increase of 6.8% for the previous 12 months. In the previous decade only twice was a figure of 10% exceeded and from 1955 (apart from a small increase in 1958) there had been a regular decline in the rate of change of consumer demand.

U.S. Equipment for the IAEA

The IAEA has accepted an offer of equipment to the value of $200,000 made by the U.S. The equipment is intended for projects under the Agency's technical assistance programme and relates to the period ending June 30, 1960. The United States has also been generous to the IAEA's laboratory, and the United Kingdom Government is being urged by manufacturers in this country to make British equipment available to maintain the prestige of British manufacturers.

Spain Requires 750MW Nuclear Capacity by 1972

In his paper to the New York Nuclear Congress the Director of CENUSA outlined the requirements of Spain for nuclear capacity in the next 15 years. Madrid will require a 250 MW plant by the end of 1968 to be augmented by a second at the end of 1972. In between these two, a third 250 MW plant will be required at Seville by the end of 1970. The Valencia area will not be requiring nuclear capacity before 1974. The suggestion was made that the first three plants mentioned should be considered as one continuing project.

Experimental Work at ISPRA

The transfer of the ISPRA research centre to Euratom has still not been ratified although the acting director general, Dr. Franco (now chief engineer of the DRAGON project) in an interview with Atomo e Industria expressed the opinion that " we must be fully confident in the agreement." The centre is currently undertaking fuel element irradiation tests for NPPC and Agip Nucleari and is shortly replacing the 20% fuel elements of ISPRA-I with 90% enriched material.

GNOME Project Approved

The AEC has approved the beginning of construction and site preparation for project GNOME, part of the AEC's ploughshare programme. A nuclear explosion will be set off at the end of a 1,100-ft tunnel 1,200 ft under the ground in the salt beds 25 miles south east of Karlsbad, New Mexico. Indications are that a ban on the explosion of military weapons will not affect the project. Object of the test is to determine whether useful power or radioisotopes can be obtained by this method as well as making cross section measurements and further investigating the characteristics of underground explosions.

DFR Completes First Operational Period

The first series of experiments on DFR which has been loaded with stainless steel clad elements containing 45% enriched uranium and natural uranium (in the proportion two parts to one) has been completed and the reactor shut down. Maximum power reached during experiments was 50 kW. During the three months shut-down period a new core comprising tubular fuel elements clad in niobium and vanadium will be installed and necessary modifications and repairs to the coolant circuits made.

EL-4 Site Selected

France's natural uranium, heavy water moderated, gas-cooled reactor is to be built on a site in Britanny about 30 kilometres south of Morlaix. The reactor itself will be the responsibility of the CEA and the conventional side of the equipment of EDF. Output of the plant is to be 80 kW electrical net.

U.S./Yugoslavian Bi-lateral Agreement

An agreement was signed in Washington on April 1 between representatives of Yugoslavia and the United States for collaboration in atomic energy development. The agreement follows the general lines of the majority of US bi-laterals; this is the first to be signed between America and a Communist country.

Ghana Joins the IAEA

Ghana has been unanimously recommended by the IAEA's Board of Governors for membership of the Agency; this will be put to the general conference meeting in September. The membership of China is still, however, opposed (by the United States particularly) in spite of its growing interest in nuclear energy matters and its installation of research equipment.

Industrial Uses of Uranium

With vast stocks of depleted uranium accumulating from the diffusion plants the Oak Ridge office of the AEC commissioned two new studies to promote commercial application of the material. Reports were prepared by the Battelle Memorial Institute in co-operation with Union Carbide; these conclude that there exist a number of potential commercial uses but considerable research and development will be necessary to exploit them.

Thermonuclear-produced Neutrons Reported in Experiments with Scylla-2

Los Alamos believe that they have produced thermonuclear reactions resulting in neutron admission. It is estimated that a temperature of 13 million degrees was reached and over the pulse period of a little under one microsecond 10^7 neutrons were emitted. Scylla-2 is a linear device comprising a tube surrounded by a single turn profiled conductor through which a high current is pulsed, creating a fast magnetic compression in a mirror geometry. The bare results differ little from those quoted at Geneva but apparently confidence in a thermonuclear origin for the neutrons has built up.

Reactor Briefs

Spert-II went critical on March 11 at NRTS, Idaho. . . . The 5-MW Tower Shielding Reactor-II, at Oak Ridge, achieved criticality on March 26.

Mobil's stand at the Exposition in New York Coliseum dealt with oils for nuclear power station applications.

The New York Atomic Exposition

France and Canada Link with U.S. Exhibit

THIS year the United States will sponsor two completely separate nuclear exhibitions. The first of these—optimistically entitled "The 6th International Atomic Exposition"—was staged in New York just before Easter. The second will be on the Pacific coast, at San Francisco, in December.

In many ways the decision to hold two exhibitions in one year is typical of the present state of the American nuclear industry—an outward manifestation of the continuing struggle between the politician and the industrialist. That is not to suggest that politicians have created the exhibition impasse; it is just that rival exhibition organizers have even succeeded in dividing the commercial side of the American industry into two camps.

This division of effort and time and money must obviously influence the impact of both exhibitions and one can only hope that this sort of folly will not be repeated again. Next year, perhaps, may see a change of heart—a closer integration of forward thinking by the industry's leaders is necessary to ensure a concentrated effort on the sales side.

The exhibition at the N.Y. Coliseum was run by a private company on behalf of the Engineers Joint Council Inc.—an association representing some 28 engineering and scientific organizations. Concurrently with the exhibition, the E.J.C. sponsored the 1960 Nuclear Congress at which more than 60 papers were presented.

The description "International" applied to the Exposition was something of a misnomer. True, foreign exhibitors included 17 from Canada, 15 from France and one from Switzerland, but the first two countries each provided a joint exhibit. Furthermore, of the 90 American companies who took space a fair proportion are not specifically engaged in nuclear work.

Turning now to the principal U.S. companies at the show the most important so far as reactor construction is concerned included AMF Atomics, Allis-Chalmers, Atomics International, Combustion Engineering, General Atomics, General Electric and Westinghouse.

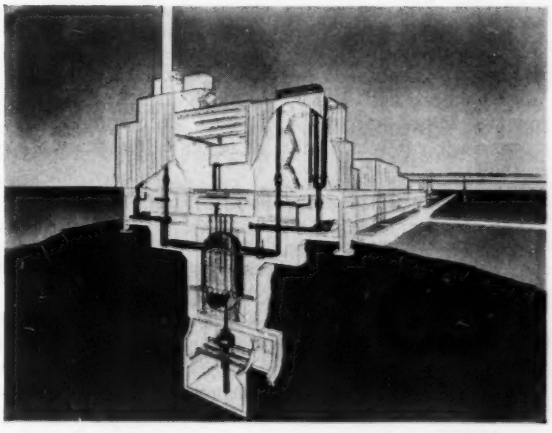
Perhaps the most revealing feature of all these exhibits was the simple fact that only one was essentially concerned with the sale of power reactors. The lack of sales pressure in this direction was all the more surprising in view of the many major U.S. reactor projects which are nearing completion.

AMF Atomics display of equipment concentrated on master-slave manipulators—both the standard model 8 and a new heavy duty version capable of moving up to 100 lb from side to side or back and forth in the fully contracted position or 65 lb fully extended. Also shown: the high pressure rack and pinion control rod drive mechanism similar to the units supplied to Argonne National Laboratory for the uprated (100 MW) EBWR. These items were presented against a background of AMF's extensive work in the research reactor business.

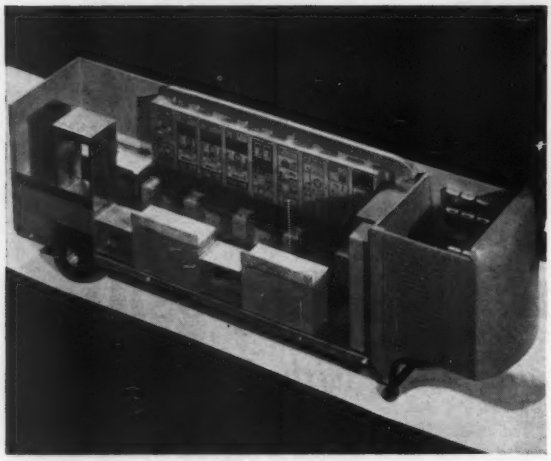
Atomics International concentrated on their facility for the remote examination of radioactive materials. Said to be "the world's largest privately owned," the 290-acre nuclear field laboratory is located in the Santa Susana mountains near Los Angeles. Shown in model form, it comprises critical experiments laboratories, six nuclear reactors, and support equipment.

General Atomics' wide range of nuclear activities must have posed something of a problem for the company's exhibition organizers. The result however was an interesting three-part display covering the very successful TRIGA research reactors, the HTGR and MTGR programme and direct conversion.

General Electric's stand was, in the main, concerned with two diverse lines of development—nuclear propulsion for aircraft and reactor instrumentation. Working models of the first-mentioned item demonstrated the way by which a reactor could replace a chemical combustion system to heat air fed into the turbojet unit providing thrust. The full-size instrumentation panel was from Dresden's control system and instrumentation engineers demonstrated in a practical way the manner in which spurious scram signals are cancelled out.



Artist's impression of the 85 MW(E) gas-cooled power reactor being developed by Allis-Chalmers.



For accurate radiation measurement at remote spots, General Electric have designed and built this semi-articulated trailer shown in model form.

Combustion Engineering—who last year acquired General Nuclear Engineering—used a series of illuminated cutaway drawings to illustrate the company's diverse nuclear activities. Like most boilermakers who enter this field there is obviously some conflict between that part of the company organized for traditional (or fossil-fired) plant and nuclear work. In spite of the company's excellent background—particularly its contribution to PWR, BWR, Packaged Power, Gas and Liquid Metal systems—there was a lack of urgency about the presentation.

Westinghouse, too, seemed to falter by not stressing to a greater extent the company's achievements in the power reactor field. True, one of the highlights of the stand was an operational mock-up of a BR.3 control rod actuator, but this surely is only a relatively minor facet of the progress made in power reactor development.

Possibly in order to make up for the shortcomings of the remainder of the reactor constructors Allis-Chalmers chose to feature three varied paths to power reactors. The highlight was an animated scale model of the first nuclear power plant designed to include a reactor with integral nuclear superheater, the Pathfinder station. The 66 MW (E) plant for Northern States Power Co. will be built at Sioux Falls, S.D.

Another important Allis-Chalmers project involves the construction of an 85 MW (E) helium-cooled, graphite-moderated reactor at Oak Ridge (Tenn.). AEC selected Allis-Chalmers and Kaiser Engineers to perform preliminary design and engineering of this complete gas-cooled nuclear power system. A model of this reactor was on show.

A third cutaway model depicted the 22-MW (E) power reactor presently under construction at Elk River (Minn.), for the Rural Co-operative Power Association. Using a conventional coal-fired superheater, this reactor will operate with the existing RCPA power plant.

Martin Nuclear Division—although not yet engaged in large-scale power reactor work—have a number of small power projects in hand. PM 1, shown in model form, will be installed next year at Sundance Air Force Station, Wyoming. This PWR is transportable by air; power rating is 1 MW(E) and the reactor will also supply 7 million B.t.u./hr of steam for heating buildings. Martin are also concerned with isotopic power systems for space flight. The latest unit is fuelled with 19,000 curies of strontium-90, the output being 5 watts at 4 V.

Nuclear fuel suppliers and companies specializing in nuclear metals were well represented. Mallinckrodt Nuclear—the first private company to provide facilities for producing enriched uranium compounds for commercial use—have already processed over 300,000 lb of uranium compounds. The company holds contracts for the supply of fuel for Dresden, Yankee and Indian Point. Nuclear fuels were also featured by Vitro and M. and C. Nuclear.

M. and C.—now a subsidiary of Texas Instruments—announced at the Exposition that it is now producing uranium, thorium and other metal foils in thinner gauges and wider strip than was previously available. New strip width is 12 in. while the thickness can be 0.0005 in.

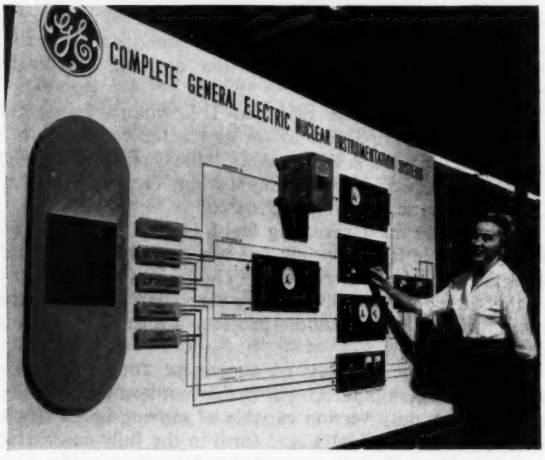
The Wah Chang Corporation now offer a range of high purity metals: zirconium, columbium, tantalum, tungsten, molybdenum and hafnium. These materials are available in ingot, rod, wire or sheet form.

A new equipment on the stand of Nuclear Materials and Equipment Corporation should prove interesting to those engaged in metallurgical research. The 4 CVE cathodic vacuum etcher provides a simple method of developing the structure of metals, ceramics and cermets for optical or electron microscopic examination. Another research tool with some application for training students was a 100 kV ion accelerator shown by Texas Nuclear Corporation.

A complete line of scintillation and optical crystals could be seen on the stand of Harshaw Chemical.

Mention has already been made of one remote handling manipulator on the stand of AMF Atomics. Hughes Aircraft' approach to this problem is somewhat similar to the device shown at Geneva, 1958, by Argonne National Laboratory. The Hughes Mobot Mk. IB is a remotely controlled robot with a pair of TV cameras feeding information to two monitors on the operators' control console.

An almost bewildering variety of remote handling devices is manufactured by Central Research Laboratories: Model 4 for over-wall installation; Model 8, master-slave; electrically powered lateral rotation of the slave arm for a Model 8; Model A, sealed master-slave manipulator; and Model B, pool manipulator. Teleflex were showing their control system based on a helical cable and hobbed wheel which drives the cable in tension and compression.



Complete instrumentation systems for power reactors are marketed by General Electric.

Canada

As might be expected several of the Canadian exhibitors represented mining interests — Consolidated Denison, uranium oxide and refined uranium products, Eldorado Mining and Refining, the ceramic uranium dioxide uranium metal and concentrates, and Gurnar Mines, uranium oxide and refined uranium products.

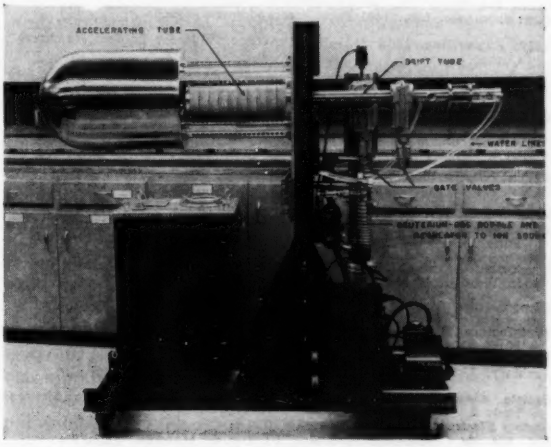
AMF Atomics (Canada) are currently manufacturing fuel elements for Canadian research and power reactors including extrusion-bonded aluminium-clad plates of metallic uranium for NRU, aluminium-clad unbonded bars for NRX, Swiss DIORIT and Canada-India and unbonded rods of high density uranium dioxide clad with Zircaloy or aluminium alloys for NPD-2 and CANDU power reactors and the ZED-2 research reactor. Models of these elements were on display. Fuel element manufacture was also featured by Canadian General Electric—particularly the various stages involved in producing nuclear fuel for NPD-2. The company, which is prime contractor for this project, also has a design study contract for the 40 MW(t) OCDR (Organic-cooled Deuterium Reactor).

In-reactor loops with heat removal capacity of from 250 kW to 1,500 kW have been developed by Canadian Westinghouse and the company offers its services for the design and supply of such equipment. Orenda Engines—a member of the Hawker Siddeley Group—also have a nuclear design team: the company's exhibit included a model of the JASON reactor marketed by Hawker Siddeley Nuclear Power.

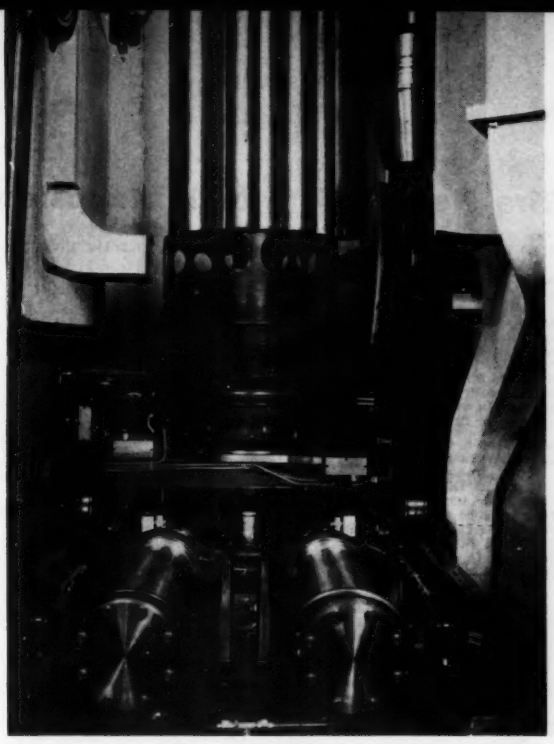
Reactor components were also featured elsewhere on the Canadian stand. Sorel Industries' display panel illustrated a calandria vessel for NRU, plug flasks for Canada/India and tube mechanism plugs made by the company. Velan Engineering, who have developed a line of high pressure high temperature forged bonnetless valves for nuclear applications, featured examples.

Both radiation detection and isotope utilization are well catered for in Canada. Atomic Energy of Canada offer the self-contained Gammacell 220 for high gamma irradiation; Electronic Associates make geiger tubes and equipment utilizing radioisotopes; Merck and Co. synthesize compounds of both stable and radioactive isotopes; Nuclear Enterprises specialize in scintillometers and scintillation plastics; RCA Victor have developed a silicon junction alpha detector; whilst Sarnia offer inspection services using radioactive sources.

Three other companies on Canada's joint exhibit, B. D. Bohna and Co., Ontario Research Foundation, and Canadian Engineering (International) provide consultancy services. The first-mentioned company has developed a pneumatic system of placing high density concrete for radiation shielding.



100 kV ion accelerator by Texas Nuclear Corporation.



Hispano-Suiza are providing this charge/discharge machinery for France's EDF 1.

The French Exhibit

With the assistance of A.T.E.N. (Association Technique pour la Production et l'Utilization de l'Energie Nucléaire) some 14 companies from France jointly featured their products and services. The largest French contribution was by the French AEC. The three-part display dealt with: (1) the extraction and concentration of uranium; (2) nuclear materials and fuels, and (3) a general survey of the Commission's achievements.

Hispano-Suiza's activities in nuclear engineering range from the manufacture of fuel handling equipment to time/flight spectrometers and from special compressors to electrically operated valves. The company displayed two components of the charge/discharge equipment it is manufacturing for EDF 1.

Pechiney's exhibits included machined samples of nuclear grade graphite, beryllium and beryllium oxide and other materials of nuclear interest. Ultra-pure metals and the chemical treatment of uranium ores were featured by Kuhlmann, whilst the Societe Electrometallurgie du Planet showed samples of their calcium which is used for uranium reduction.

From the reactor design and construction angle, Groupement Atomique Alsacienne Atlantique displayed photographs of work that its constituent companies have done for the G.2, G.3 and E.L.3 reactors.

Other French exhibitors included: Appareils Gachot (seamless, bellows-type valves); Societe Jahan et Cie (dry boxes for micro-handling); Saint-Gobain (LIP magnetic manipulator and a Barras parallelogram type manipulator); Siersatom (2 decrimping machines for irradiated tubes); Manufacture Française de Vide-Touries Automatiques (stopcocks in PVC); Compagnie Française des Meteux (heat exchanger plates and tubes); Societe Alsacienne (ionization chamber); Societe Industrielle (fuel element cartridges).

The New York Atomic Exposition — EXHIBITORS

AMF Atomics Div., American Machine and Foundry Co., 140 Greenwich Avenue, Greenwich, Conn.
Ad-O-Plastic, 240 Amboy Avenue, Woodbridge, N.J.
Aeroquip Corp., Marman Div., 11214 Exposition Boulevard, Los Angeles 64, Calif.
Aetna Casualty and Surety Co., 151 Farmington Avenue, Hartford 15, Conn.
Allis-Chalmers Manufacturing Co., P.O. Box 512, Milwaukee 1, Wis.
American Potash and Chemical Corp., See Lindsay Chemical Div.
Anton Electronic Laboratories, 1226 Flushing Avenue, Brooklyn 37, N.Y.
Assembly Products, Inc., 75 Wilson Mills Rd., Chesterland, Ohio.
Atom Industry, 408 Madison Avenue, New York 17, N.Y.
Atomics International Div., North American Aviation, Inc., P.O. Box 309, Canoga Park, Calif.

BJ Electronics, Borg Warner Corp., 3300 Newport Boulevard, Santa Ana, Calif.
Bendix Aviation Corp.
Bendix Products Div., 401 N. Bendix Drive, South Bend 20, Ind.
Cincinnati Div., Cincinnati, Ohio.
Computer Div., 5630 Arbor Vitae Street, Los Angeles, Calif.
The Beryllium Corp., P.O. Box 1462, Reading, Penna.
Brookhaven Industrial and Advisory Committee, P.O. Box 232, Patchogue, N.Y.
The Brush Beryllium Co., 5209 Euclid Avenue, Cleveland 3, Ohio.
Burroughs Corp., Electro Data Div., 460 Sierra Madre Villa, Pasadena, Calif.
Byron Jackson Pumps, Inc., Borg Warner Corp., 2300 E. Vernon Avenue, Los Angeles 54, Calif.

Cambridge Filter Corp., P.O. Box 1255, Syracuse 1, N.Y.
Central Research Laboratories, Inc., Red Wing, Minn.
Charleston Rubber Co., Stark Industrial Park, Charleston, S.C.
Combustion Engineering, Inc., 200 Madison Avenue, New York 16, N.Y.
Conference Book Service, 3209 Columbia Pike, Arlington 4, Va.
Consolidated Controls Corp., Durant Avenue, Bethel, Conn.
Consolidated Siphon Supply Co., Inc., Terriss Div., 22 Wooster Street, New York 13, N.Y.
Consultants Bureau Enterprises, Inc., 227 West 14th Street, New York 11, N.Y.
Controlled Atmosphere Enclosures, Jacksonville 6, Fla.
Controls for Radiation, Inc., 130 Alewife Brook Parkway, Cambridge, Mass.
Cooper Metallurgical Associates, Box 3991, Cleveland 20, Ohio.
Crossroads Marine Disposal Corp., 26 T Wharf, Boston, Mass.

Damascus Tube Co., Greenville, Penna.

Elcor Inc., 1225 W. Broad Street, Falls Church, Va.
Encyclopedia Britannica, 551 Fifth Avenue, New York, N.Y.
Erskine-Healy, Inc., 420 St. Paul Street, Rochester 5, N.Y.

Flanders Filters, Inc., P.O. Box 718, Riverhead, N.Y.
Florida Development Commission, Carlton Building—East Wing, Tallahassee, Fla.
Ford Instrument Co., 31-10 Thomson Avenue, Long Island City 1, N.Y.
Foster Engineering Div. See Hammel-Dahl Div.

General Controls Co., 801 Allen Avenue, Glendale 1, Calif. See also Hammel-Dahl Div.
General Dynamics Corp., General Atomic Div., P.O. Box 608, San Diego 12, Calif.
General Electric Co., 1 River Road, Schenectady, N.Y.
Atomic Power Equipment Department, San Jose, California.
Aircraft Nuclear Propulsion Department, Cincinnati 15, Ohio.
Griscom-Russell Co., Massillon, Ohio.

Hagan Chemicals and Controls, Inc., P.O. Box 1346, Pittsburgh 30, Penna.
Hammel-Dahl/Foster Engineering Div., General Controls Co., Warwick Industrial Park, Warwick, R.I.
Hamner Electronics Co., Inc., P.O. Box 531, Princeton, N.J.
The Harshaw Chemical Co., Crystal Div., 1945 E. 97th Street, Cleveland 6, Ohio
Harvey Aluminium, 19200 S. Western Avenue, Torrance, Calif.
Health Education and Welfare Department of Social Security Administration, 1657 Broadway, New York 19, N.Y.
Hughes Aircraft Co., Culver City, Calif.

Instron Engineering Corp., 2500 Washington Street, Canton, Mass.
The International Nickel Co., Inc., 67 Wall Street, New York 5, N.Y.

Kaman Aircraft Corp., Nuclear Div., Colorado Springs, Colo.
Kollmorgen Optical Corp., 347 King Street, Northampton, Mass.

The Landsverk Electrometer Co., 641 Sonora Avenue, Glendale 1, Calif.
Lear, Inc., 110 Ionia, N.W., Grand Rapids, Mich.
Lerma Engineering Corp., P.O. Box 168, Northampton, Mass.
Librascope Div., General Precision, Inc., 808 Western Avenue, Glendale 1, Calif.
Lindsay Chemical Div., American Potash and Chemical Corp., 99 Park Avenue, New York 16, N.Y.
Lockheed Nuclear Products, 3272 Peachtree Road, N.E., Atlanta 5, Ga.
Lundell and Co., 7356 Wood Lawn Avenue, Chicago 19, Ill.

M and C Nuclear, Inc., Subsidiary of Texas Instruments Inc., P.O. Box 898, Attleboro, Mass.
Mallinckrodt Nuclear Corp., 3600 North Second Street, St. Louis, Mo.
Marion Laboratories, Inc., 4500 East 75th Terrace, Kansas City, Mo.
The Marquardt Corp., 16555 Saticoy Street, Van Nuys, Calif.
The Martin Co., Nuclear Div., G-3037, Baltimore 3, Md.
Marvel-Schebler Products Div., Borg-Warner Corp., P.O. Box 863, Decatur, Ill.
Minneapolis-Honeywell Regulator Co., Wayne and Windrim Avenues, Philadelphia 44, Penna.
Mobil Oil Co., 150 E. 42nd Street, New York, N.Y.

National Lead Co., 111 Broadway, New York 6, N.Y.
New York State, Atomic Energy Development Commission, Albany, N.Y.
North American Aviation, Inc. See Atomic International Div.
North American Van Lines, Inc., New Haven Ave. at Meyer Road, Fort Wayne, Ind.
Nuclear Data, Inc., 145 N. Washington St., Wheaton, Ill.
Nuclear Development Corp. of America, 5 New St., White Plains, N.Y.
Nuclear Materials and Equipment Corp., Apollo, Penna.
Nuclear Measurements Corp., 2460 N. Arlington Avenue, Indianapolis 18, Ind.
Nucleonic Corporation of America, 196 Degraw Street, Brooklyn 31, N.Y.
Nucleonics, 330 West 42nd Street, New York 36, N.Y.

Oerlikon Engineering Co., Zurich, Switzerland.

Pacific Coast Engineering Co., P.O. Drawer E, Alameda, Calif.
Packard Instrument Co., Inc., P.O. Box 428, La Grange, Ill.
Pergamon Press, Inc., 122 East 55th Street, New York 22, N.Y.
Permali, Inc., P.O. Box 718, Mount Pleasant, Penna.

RCA Service Co., Cherry Hill, Delaware Township, Camden 8, N.J.
Radiation Counter Laboratories, Inc., 5121 W. Grove Street, Skokie, Ill.
Radiation Instrument Development Lab., Inc., 5737 South Halsted Street, Chicago 21, Ill.
Ray Proof Corp., Stamford, Conn.
Research Equipment Co., P.O. Box 127, Glen Ellyn, Ill.
Reuter-Stokes Electronic Components, Inc., 2149 Hamilton Avenue, Cleveland 14, Ohio.
Riggs Nucleonics Corp., 135 West Magnolia Boulevard, Burbank, Calif.

Small Business Administration, Research and Development Section, 42 Broadway, New York 4, N.Y.

Technical Associates, 140 West Providencia Avenue, Burbank, Calif.
Technical Measurement Corp., 441 Washington Avenue, North Haven, Conn.
Teleflex, Inc., P.O. Box 218, North Wales, Penna.
Texas Nuclear Corp., P.O. Box 9267, Allandale Station, Austin 17, Texas.
Thompson Ramo Wooldridge, Inc., Canoga Park, Calif.
The Timken Roller Bearing Co., Steel and Tube Div., 1835 Dueber Avenue, S.W., Canton 6, Ohio.
Tracerlab, Inc., Reactor Monitoring Center, 2030 Wright Avenue, Richmond, Calif.

Union Carbide Corpn., 30 East 42nd Street, New York 17, N.Y.
United Nations, 1st Avenue and 42nd Street, New York, N.Y.
U.S. Atomic Energy Commission, Washington 25, D.C.
U.S. Nuclear Corp., P.O. Box 208, Burbank, Calif.
United States Steel Corp., 525 William Penn Place, Pittsburgh 30, Penna.

D. Van Nostrand Co., Inc., 120 Alexander Street, Princeton, N.J.
Vard, a Division of Royal Industries, Inc., 2981 E. Colorado Street, Pasadena 8, Calif.
The Victoreen Instrument Co., 5806 Hough Avenue, Cleveland, Ohio.
Vitro Corporation of America, 261 Madison Avenue, New York 16, N.Y.

Wah Chang Corp., 233 Broadway, New York 7, N.Y.
Westinghouse Electric Corp., Atomic Power Department, P.O. Box 355, Pittsburgh 30, Penna.

CANADIAN EXHIBITORS

Canadian Department of Trade and Commerce, 479 Bank Street, Ottawa, Ontario.

AMF Atomics, Ltd., Port Hope, Ontario.
Atomic Energy of Canada, Ltd., Commercial Products Div., P.O. Box 711, Ottawa, Ontario.

B. D. Bohna and Co., Ltd., 1070 Hornby Street, Vancouver 9, B.C.

Canadian Engineering Co., Ltd., Shell Tower Building, Montreal, Quebec.
Canadian General Electric Co., Ltd., 107 Park Street, Petersborough, Ontario.
Canadian Westinghouse Co., Ltd., 286 Sanford Avenue North, Hamilton, Ontario.
Consolidated Denison Mines, Ltd., 360 Bay Street, Toronto 1, Ontario.

Eldorado Mining and Refining, Ltd., Port Hope, Ontario.
Electronic Associates, Ltd., 4616 Yonge Street, Willowdale, Ontario.

Gunnar Mines, Ltd., 25 Adelaide Street West, Toronto 1, Ontario.

Merck and Co., Ltd., P.O. Box 899, Montreal 3, Quebec.

Nuclear Enterprises, Ltd., 1750 Pembina Highway, Winnipeg 9, Manitoba.

Ontario Research Foundation, 43 Queen's Park, Toronto 5, Ontario.
Orenda Engines, Ltd., Box 4015, Terminal "A," Toronto 1, Ontario.

R.C.A. Victor Co., Ltd., 1001 Lenoir Street, Montreal 30, Quebec.

Sarnia Inspection Co., 280 Tecumseh St., Sarnia, Ontario.
Sorel Industries, Ltd., 1405 Peel Street, Montreal, Quebec.

Velan Engineering, Ltd., 2124 Ward Avenue, Ville St. Laurent, Montreal 9, Quebec.

FRENCH EXHIBITORS

A.T.E.N., 4 Rue de Teheran, Paris 8.
Appareils Gachot, 179 Avenue de la Division Leclerc, Enghien (S. and O).

Commissariat a l'Energie Atomique, 69 Rue de Varenne, Paris 7.
Compagnie de Saint-Gobain, 62 Boulevard Victor-Hugo, Neuilly S/Seine.

Etablissement Jahan, 24 Rue des Gravilliers, Paris 3.
Etablissements Kuhlmann/Simo, Caratom, 25 Boulevard de l'Admiral Bruise. Paris 16.

Groupment Atomique Alsacienne Atlantique, 100 Avenue Adouard Herriot le Plessis-Robinson.

Hispano-Suiza France, Rue Guynemer, Bois-Colombes.

Manufacture Francaise de Vide-Touries Automatiques, 169 Avenue Victor Hugo, Paris 16.

Pechiney, 23 Rue Balzac, Paris 8.

Societe Alsacienne de Constructions Mechaniques, 69 Rue de Monceau. Paris 8.
Societe Electrometallurgique de Planet, 9 Rue Chauchat, Paris 9.
Soc. Ind. de Combustible Nucleaire, 69 Rue de Monceau, Paris 8.
Societe Industrielle d'Etudes et de Realisations Scientifiques, 108 Avenue du Maine, Paris 14.

SWEDEN'S NUCLEAR PROGRAMME

Although still undecided the Swedish nuclear power programme is expected to emerge along firmer lines next year. The diversity of the plans as they are at the moment are examined in relation to the anticipated power demand.

THE Swedish nuclear energy programme has been in a state of flux since the ambitious plans announced in 1955 and 1958 at Geneva, and although still largely undecided, should emerge along more definite lines early next year. The real need for additional power other than hydro-power is becoming more obvious, and although oil-fired plants will probably account for the greater part of the additional installed thermal capacity in the next 5 to 10 years, the desirability of nuclear fuels assuming a steadily increasing importance is generally acknowledged.

A reasonable estimate of the new nuclear capacity, after 1970, is about 400 to 450 MW per year, viz., approximately 50% of the total expected installation of 800-900 MW/an. But, as Sweden is the largest importer and user of oil for power in Europe, this percentage could markedly increase should oil prices rise steeply or serious shortages again occur. It is unlikely that oil prices will ever fall significantly below their present level. The national policy has been to spread oil contracts over as wide an area throughout the world as possible to date, but economists in Sweden agree that a total reliance on oil is out of the question.

The economics of hydro-power are subject to seasonal variations. As a result of an exceptionally dry summer last year, old inefficient thermal stations had to be utilized at high load factors; electricity had to be imported from Denmark, and laid-up oil tankers had to be used to supply additional power from their generating plants. The dry summer resulted in industrial production in parts of Sweden being reduced and should another occur this year, a serious situation could develop. An important economic consideration in the future installation of oil-fired power stations is that facilities do not exist for large-scale stockpiling and although some expansion is in hand, the heavy cost of these installations adversely affects the overall cost of power from oil-fired stations.

PRESENT POSITION

Briefly the position of the nuclear bodies at the moment is this:

1. The State Power Board produce about 40% of the electrical output and as they are governmental controlled are, to a large extent, dependent upon government decisions.

2. AKK are a consortia comprising about 75% of the private generating industry and municipalities, who, with the independent 25%, produce about 60% of the total electrical output.

3. AB Atomenergi are a company formed by the State, which holds the majority of the shares (four-sevenths), and 71 private and municipal shareholders. Their main purpose is to act as a central body for applied research and development work. This includes the industrial application of nuclear power.

4. The Delegation for Atomic Energy Questions are a governmental advisory committee, and as the granting of licences for reactor operation is a governmental responsibility, it is they who make final decisions as to what lines Sweden should follow in nuclear power development, and which plants can be built.

5. ASEA of Västerås are the largest of a number of concerns with nuclear development departments.

HEAVY WATER CONCEPTS

The governmental policy, along with that of AB Atomenergi, is to develop the Swedish concept of heavy-water, natural uranium as at least a part of the future nuclear programme. In some quarters there is almost a dedication towards carrying this concept to the ultimate conclusion, coupled with a belief that it will eventually prove economical. The R3/Adam project (see p. 202), the

first in this line, in spite of many difficulties, is continuing and the reactor should go critical towards the end of 1962. ASEA are now responsible, in conjunction with AB Atomenergi, for the final design of this electricity/district heating, dual purpose plant. The follow-on project is R4/Eve a 100 MW(e) (electricity generation only, but with design capacity of up to 400 MW) pressurized, heavy-water moderated and cooled reactor using natural uranium fuel. The fuel will be similar to R3/Adam, uranium dioxide with Zircaloy cladding.

It is to be constructed above ground, spherically contained in mild steel, with all surfaces exposed to heavy water of stainless steel. The basic design is fundamentally the same as R3/Adam with a higher specific output and five S.R.U.s against four in R3/Adam. Another alteration will be to the reactor top which will be domed-shaped instead of flat. The pressure vessel will be of carbon or low alloy steel with stainless-steel cladding. Plans are being worked on now which may allow the reactor to be unloaded and loaded under full power. The proposed site for this concept is at Vikbolandet near Norrköping, south of Stockholm.

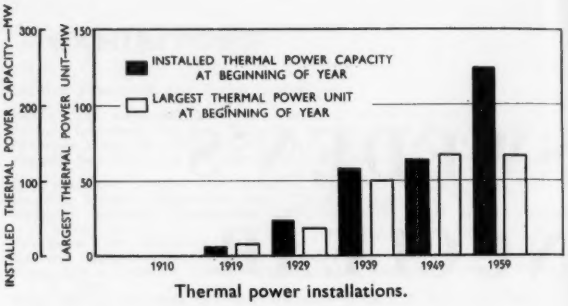
MAJOR DEPARTURE

It should be pointed out at this stage that the proposal to build this station above ground is a major departure from the Swedish concept of the R3/Adam station, which is built in solid rock, the traditional Swedish mode of construction. Not only is there a long background of experience in building hydro generating stations in rock but R3/Adam is built on this principle and many regard the most important Swedish contribution to nuclear engineering to be this very technique. R4/Eve would, however, be so large that such interment of the plant is thought to be much more expensive than an above ground construction. A further cause for concern in these types is the reactivity of the core, which may require enrichment for criticality to be achieved. As the main incentive in the development of the heavy water plant is to avoid enrichment the reactivity assessment is critical.

If, however, doubts on this score can be resolved—possibly by using initial seeding followed by a natural uranium feed—and the potential economics of the system can justify it, a decision to go ahead with the concept can be expected about August, 1961. The State Power Board (the potential customers) may, however, take some convincing not only about the feasibility and cost but also about the time scale. The State Power Board feel that as the potential operators of nuclear power stations they should have more control over development decisions and be more responsible for the development of power concepts. Some formal statement of their attitude and requirement for "proven economics" is expected in the near future.

MORE FAVOURABLE RESOURCES

The State Power Board produces just over 40% of the total electricity in Sweden but their hydro power resources are more favourably situated and are expected to last longer than those of private industry. They are therefore not in quite the same hurry as AKK to introduce alternative energy supplies and can possibly afford a limited delay. But they are anxious not to lose any ground to the private groups and consider that extensive operational experience is necessary before they embark upon a large nuclear programme which, after the 1970s, would amount to about 200 MW installed per year in their case. As a result they have looked towards other concepts and at one stage proposed collaborating in the AKK project. This collaboration does not appear now to have any chance of developing.

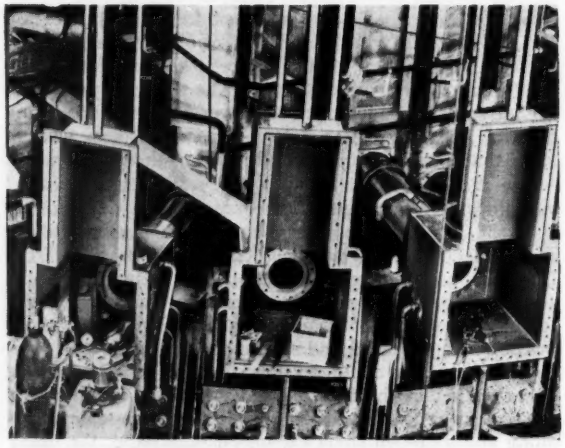


Thermal power installations.

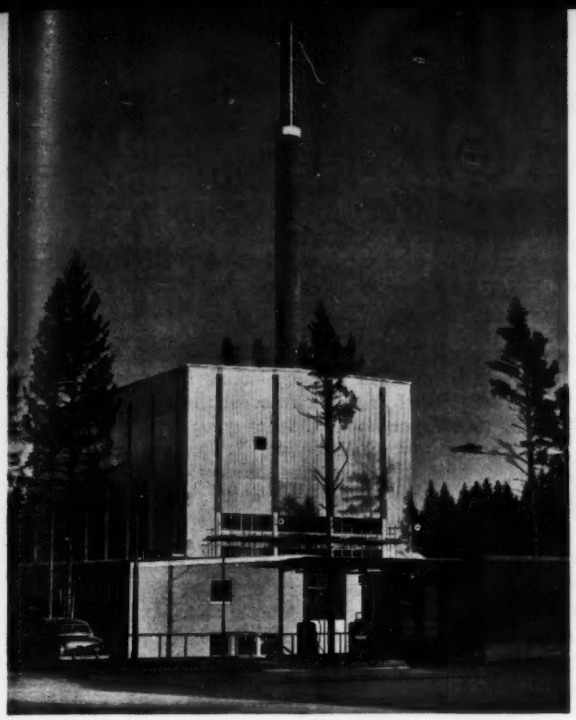
BOILING WATER PROPOSAL

The AKK proposal is to build a 50 MW boiling water reactor of the Humboldt Bay type, almost as soon as possible. They have a far greater need for additional power and are not prepared to place all their faith on thermal stations. They have asked for tenders for their proposal to be in by May 16 but no definite date has been given as to when a contract can be placed. This decision rests largely with the Government Advisory Committee, who have made a study of the proposal. They are, in principle, against the use of enriched uranium and are anxious to promote the heavy water type, but technically have little ground for refusing. They have not yet made known their final decision but AKK appear to be confident that they will be given permission to build. Even so, there is a rumour abroad that the matter will not rest there and pressure will be brought to bear upon important members of AKK to delay the start of construction although this could result in support coming from the remaining 25% of private industry.

It is difficult to believe that government influence would be used in this way, particularly in view of AKK's immediate need and the capital they have available. It is quite out of the question for them to consider a large power station costing about £30 million but a £6-8 million station could be afforded. An interesting side line to the BWR project is that this reactor could provide invaluable operating experience for future ship-builders of nuclear propelled vessels and it is significant that one of the largest shipbuilders in Scandinavia, Kockums of Malmo, in conjunction with Allis Chalmers, may be tendering. A. Johnson and Co., ship operators and large metal and ore manufacturers, are also expected to tender together



Experimental chambers in R2 which will be used primarily as a materials testing reactor.



The new building housing the R2 30 MW high flux reactor still under construction at Studsvick in south Sweden. The reactor is expected to begin operating later this year.

with Westinghouse. But the combination of ASEA and another Swedish firm, Nohab, into a firm called Reaktor Technik, in conjunction with General Electric, U.S., for the tendering for this station, makes formidable competition. Nohab are part of the Bofor group, specialists in propulsion turbines for ships and locomotives and water turbine manufacturers.

THIRD CONCEPT

A third reactor concept fulfilling two of Sweden's desired conditions is gaining increasing support. The plan is for a gas-cooled, natural uranium, graphite moderated Calder Hall type reactor to be built in solid rock, below ground level. Present designs, nearing completion, call for a 235 MW, natural uranium reactor with a rock pressure vessel protected by a liner of steel clad concrete. This concept is as much Swedish as the heavy water, natural uranium type R3/Adam and R4/Eve which owe much of their basic development to Canada. ASEA, the State Power Board of Sweden, and the Nuclear Power Group of the U.K. (formerly NPPC) are collaborating on the project.

The State Power Board are experts in rock excavation and would do all the excavating work themselves. They are confident that the excavating, although a more lengthy proposition than building above ground, can be satisfactorily undertaken and will show economic advantages. The core is basically of a proven type. But the design shows, nonetheless, important differences from that of Bradwell. With tubular fuel elements the pressure of the CO_2 coolant has been increased to about 1,000 p.s.i. This has been accomplished by placing the reactor with shielding in the rock cavern, 100 m below ground level with the walls lined with steel plates and a concrete filling between the steel plate and rock wall. The space between the reactor shield and the steel walls is filled with CO_2 at a pressure of 1,000 p.s.i. and at a temperature of 40°C. Fuel loading and unloading can be performed on-load by a single machine.

Net overall efficiency of the station is calculated to be 34%. Design modifications are under way to include the heat exchangers in the rock cavity as well, fairly close to the reactor. It is also intended to double the number of fuel channels (1,740 at present), and consideration is being given to a return to solid rods.

In comparison with the above-ground station, core size can be considerably reduced owing to the doubling of the power density due to the high pressure of the CO_2 whilst the cost of the rock pressure vessel for 1,000 p.s.i. is claimed to be no more than that of a steel pressure vessel for 150 p.s.i.

MAIN DATA

The main data for the rock-vessel power plant is:	
Nominal thermal output of fuel and graphite	688 MW
CO_2 inlet temperature	280° C
CO_2 outlet temperature	401.1° C
Pressure of outlet CO_2 above core	70.12 bars
Total flow of coolant at nominal output	4,822 kg/s
Average specific output based on 688 MW	4.35 kW/kg
Pressure drop through central channel	0.78 bars
Average gas velocity in central channel	11.9 m/s
Total number of fuel channels	1,740
Graphite, total weight	1,890 tons
Total length of tubular fuel element	1,062 mm
Total length of tubular uranium rod	943 mm
Outer diameter of tubular uranium rod	38.1 mm
Inner diameter of tubular uranium rod	22.61 mm
Wall thickness of Magnox canning	2.54 mm
Number of fuel elements per channel	7
Number of CO_2 blowers	6
Total power absorbed by blowers	15 MW
Number of heat exchangers	18
Inlet feed-water temperature	150° C
Outlet pressure of high-pressure steam	78 bars
Outlet temperature of high-pressure steam	384° C
Inlet pressure of steam to reheater	22 bars
Inlet temperature of steam to reheater	238° C
Outlet pressure of reheated steam	20.5 bars
Outlet temperature of reheated steam	367° C
Steam flow rate to high-pressure turbines	171.5 kg/s
Steam flow rate to low-pressure turbines	249 kg/s
Net electrical output	235 MW

FORMIDABLE CONCERN

In the background to all the nuclear work being undertaken in Sweden is the ASEA company of Vasteras. Already with a staff in their nuclear division of 240 and plans to increase it to 350 within a year, this company, who are the largest electrical concern in Sweden, have placed a considerable amount of faith in nuclear energy.

They are at the moment: completing the final design of R3/Adam and are main contractors for the reactor; undertaking the design for R4/Eve in conjunction with Nohab and Atomenergi; doing the design for the rock vessel reactor concept in conjunction with the Nuclear Power Group and the State Power Board; doing several design studies for another research reactor RX (the project could follow several lines); designing and tendering for the construction of the 50 MW boiling water reactor for AKK (through the amalgamated firm Reaktor Technik with Nohab and G.E.); are producing a small amount of heavy water with plans to build a facility for 30 to 40 tons a year should the demand arise; have a facility for the production of uranium oxide pellets for R3/Adam and will supply 12 tons for the first 18 tons core (the remainder will be supplied by Kohlswa Jernverk); are busy installing facilities to do the Zircaloy cladding of the fuel pellets which, when completed, will put them in the position of being able to supply the complete fuel element; are developing a new column for plutonium separation.

ASEA are therefore prepared for any lines the Swedish nuclear power programme may develop along. They already are a formidable concern and with the obvious amount of knowledge and skill in their organization, will undoubtedly become one of the major constructors of nuclear power plants in northern Europe. They—alongside several other firms—are in the position to provide a strong basis for nuclear development.

Notable among other concerns is AB Svenska Metallverken, specialists in aluminium welding and a firm with considerable confidence in nuclear power development. They have been concerned with aluminium welding work

on the R2 30-MW high flux research reactor at Studsvik, the tank for which was completed by A.P.V. of the U.K. and similar fabrication for nuclear projects in Norway, Belgium and Holland.

GENERAL SITUATION

The general situation with regard to research and legal aspects from the official side is as follows. The Ministry of Commerce are responsible for the development of nuclear energy within the framework of energy policy in general, licences for fuel and installations and for uranium and thorium ore prospecting. This Ministry also provides the operating finance for AB Atomenergi. The Ministry of Communications provide the funds for the State Power Board. The Ministry of Education is responsible for basic nuclear research and the Ministry of Interior for radiation protection. The Ministry of Foreign Affairs is responsible for nuclear matters concerning foreign countries and in general co-ordinates the activities of the other governmental agencies. All executive powers are vested, under the Ministries, in governmental and semi-governmental agencies.

FUTURE POWER PRODUCTION

The case for nuclear future power production is briefly this:

1. Sweden will need some form of installed nuclear power well before 1970 if she is to be in the position of building a reliable power production programme along nuclear lines.

2. Should another dry summer occur this year it will increase the urgency of the situation.

3. The AKK group, who have a greater and more immediate need for nuclear power development, have obstacles in their way to building their 50 MW boiling water reactor but there is no strong case against letting them spend their own money. AKK more than anyone else are anxious to embark upon a nuclear programme and to gain experience also in a marine type.

4. The State Power Board have also appreciated the need for something to be done soon (within a year or 18 months) and, as the consumers, feel they should be allowed some form of self decision.

5. It is argued that the heavy-water concept has as much prospect of becoming economical as any other and if this argument can be supported by concrete evidence, within the next 18 months, then R4/Eve should become a definite project.

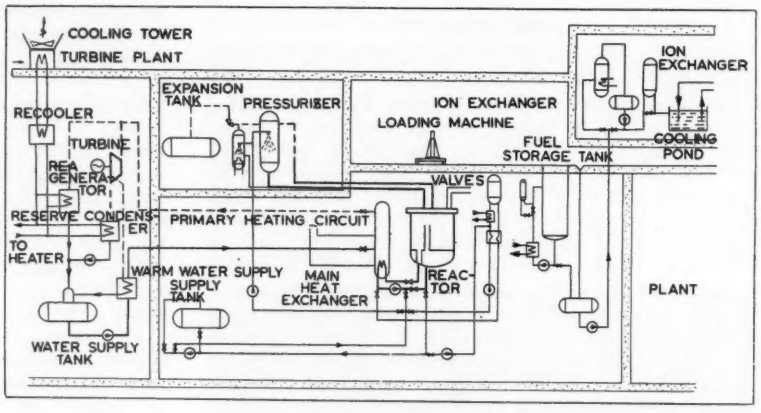
6. The Calder-type concept combines the advantages of high efficiency and a developed basic technology and unless unexpected complications arise could well form the basis for a series of similar stations.

7. There is no doubt that a large and active Swedish industry in the nuclear field is poised ready to expand once given the go-ahead.

8. There is a coming nuclear export market in Scandinavia and Swedish industry is keen to take advantage of the opportunities.

9. Internal political issues and petty rivalry have clouded and hampered the Swedish programme to quite some considerable extent, but there is a growing awareness of this and although no complete solution is imminent the positive selection of initial reactor types by the State Power Board and AKK may do much to minimize the dissension.

R3/ADAM

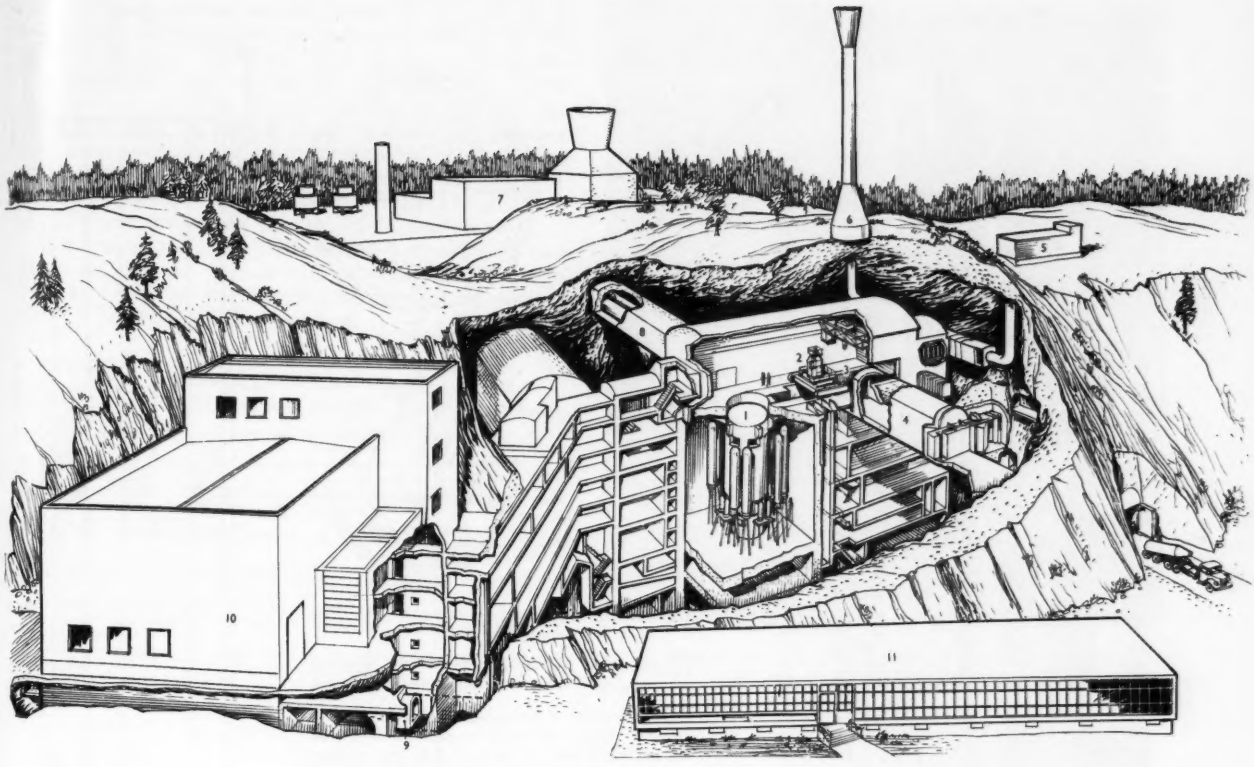


Combined Heating and Power Project

AGESTA Power and Heat Station, also referred to as R3/Adam, incorporates a heavy-water power reactor, designed for simultaneous generation of 10 MW of electrical power and 55 MW in the form of hot water for domestic heating. It is situated at Agesta (Ohguestah), about 10 miles south of Stockholm and is expected to come into operation in 1963. A description of the 1958 status of the design was given at Geneva, P/135.

The Atomic Energy Co. (AktieBolaget Atomenergi), the State Power Board (Kungl. Vattenfallsstyrelsen) and the City of Stockholm Electricity Authority (Stockholms Stads Elektricitetsverk) are building the complete station in co-operation, from both the technical and economic standpoints. For the reactor portion of the station, ASEA (Allmonna Svenska Elektriska Aktiebolaget) is co-ordinator and main contractor, with Nohab and Degerfors among others supplying major components. The Atomic Energy Company is responsible for the basic design of the reactor equipment. The complete fuel elements for the first core are to be supplied by the Atomic Energy Company. ASEA and Kohlswa Jernverk carry out the sintering of the oxide pellets as sub-contractors to the Atomic Energy Company.

The hot water from the plant will be used as a domestic



KEY

1. Reactor
2. Charge machine
3. Cooling pond
4. Fuel entrance
5. Ventilation inlet
6. Ventilation outlet
7. Water reservoir
8. Pressurizer and expansion tanks
9. Central heating return
10. Turbine Hall
11. Offices

Outline drawing of the reactor in its rock cavern.

heating source for the new suburb of Farsta, several kilometres away. The reactor has been planned to operate from 5,000 to 6,000 hours a year and will be shut down during the summer. Although the turbines, gas and water cleaning equipment and office are outside, the entire reactor is located in a rock cave.

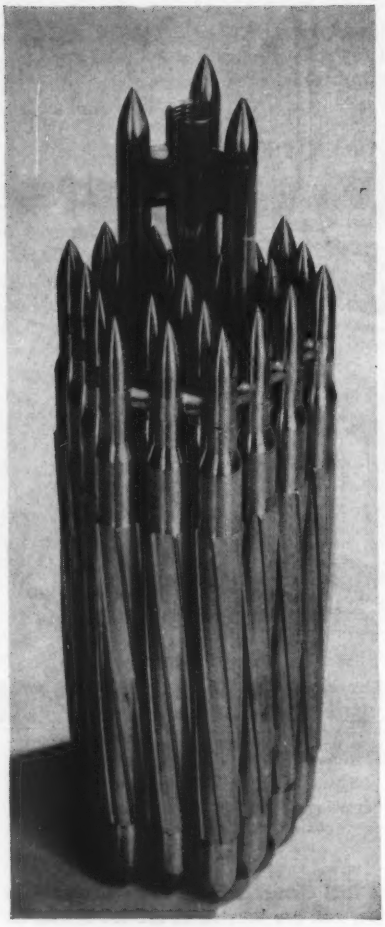
Containing 19 metric tons of natural UO_2 clad in Zircaloy, the core will have a thermal power initially of 65MW. The heavy water coolant and moderator is under a pressure of 34 atm. and reactivity calculations show that the burn-up can be about 5,000 MWd/t although with fresh fuel at full power and poisons in equilibrium excess reactivity is only 0.5%. A critical assembly will be built at Studsvik using actual fuel elements to check calculations, but it will be run at atmospheric pressure and measurements will not be at full temperature.

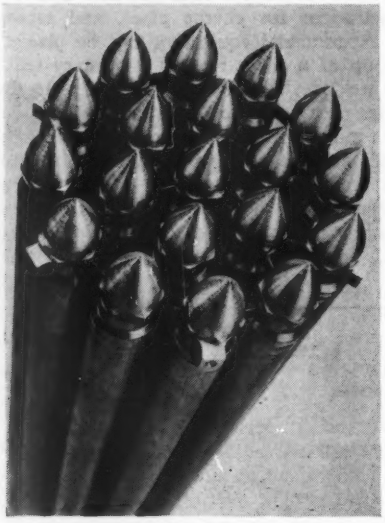
Reactor Construction

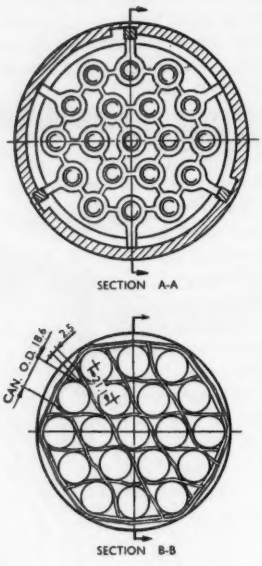
The pressure vessel is made of 70 mm steel plate clad with 5 mm stainless steel and is 6 m high with a diameter of 4.5 m. The vessel rests on a skirt welded to the bottom and the bottom section includes four inlets and four outlets for the heavy water coolant. The vessel has a flat top made up of a honeycomb of plates 50 mm thick by 1200 mm high encased between top and bottom plates of 75 mm thickness. The lower plate carries steel blocks which act both as fuel element supports and the primary thermal shield. The fuel elements hang down from hooks into the core volume, and are located at the lower end by a conical end fitting in the bottom inlet plenum. The top also includes penetrations for charge pipes, and access holes into which experimental equipment can be placed. The seal is made up of a silver ring as a primary seal, backed up by a weld seal. A system of loose flanges and rolling bearings accommodates differential expansion but this is kept to a minimum by circulating water through the top honeycomb and maintaining the temperature to closely controlled limits. The water also acts as a top shield. The reactor has 27 hydraulically operated step type coarse and safety rods with two sets of grips acting on the inside and outside of drive tubes and two fine

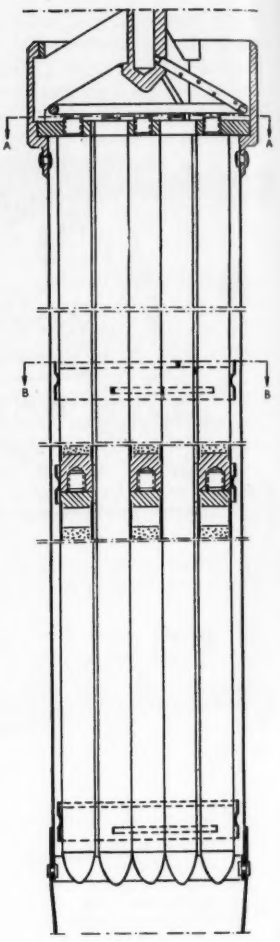
MAIN DATA

Reactor power	65 MW
Coolant, moderator and reflector	D_2O
Coolant inlet temperature	400°F
Coolant outlet temperature	430°F
Reactor pressure	495 p.s.i.g.
Working temperature of the reactor	430°F
Design pressure	570 p.s.i.g.
Design temperature	480°F
Fuel	Natural UO_2
Amount of fuel	41,900 lb
Number of fuel assemblies	140
Rods per fuel assembly	19
Canning material	Zircaloy II
Number of main coolant circuits	4
Main cooling flow	2,290 lb/sec
Pressure drop through the reactor	8:6 p.s.i.
Amount of D_2O in the reactor	116,500 lb
Total D_2O inventory	154,500 lb
Generator power	10 MW
Steam flow to the turbine	65.8 lb/sec
Amount of heat to the district heating system	55 MW
Outgoing temperature	165-250°F
Incoming temperature	130-160°F









(Upper left) An early form of fuel element using finned aluminium cladding.

(Upper right) A cross-sectional view of the current design showing in section A-A the top support and in section B-B the system of crossed-wires which space the rods in the body of the element.

(Bottom left) A model of the present tube bundle design in stainless steel.

control rods also hydraulically operated; the absorbers will be comprised of silver-indium-cadmium alloy canned in stainless steel. Fuel handling is by a gantry carried charge and discharge machine operating through the stand pipes, one pipe serving four channels, with the reactor off-load and depressurized; nitrogen is used for cooling the spent fuel elements. Fuel storage is in six stainless steel tanks with a separate one for burst elements.

Coolant Circuit

At the bottom of the tank are four 11 in. nozzles connecting the tank to the inlet plenum of the elements and four 11 in. outlet nozzles taking flow from the bulk moderator/coolant. The water is circulated up through the fuel bundles and down past the outside of the elements to the four main U-type heat exchangers arranged around the reactor on fixed foundations; thermal motions are taken up by flexibility in the pipes. The main loops are of 9 in. stainless steel piping and flow is 2,100,000 lb/h giving a velocity in the pipes of 21 ft/sec.

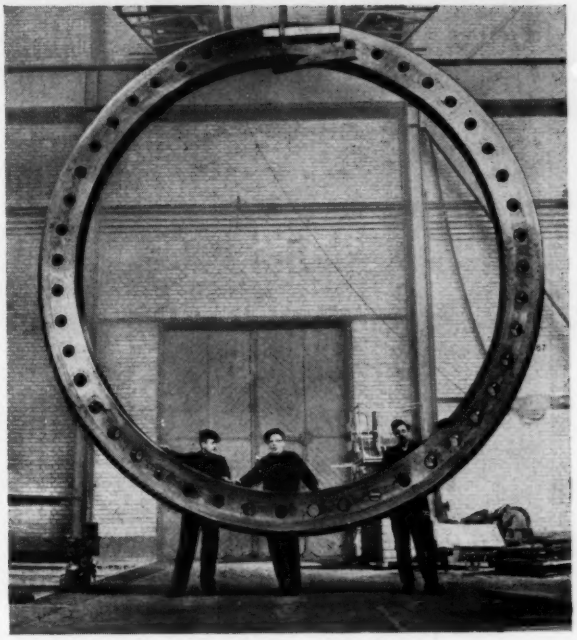
The pressurizer vessel is 8 ft in diameter and 14 ft high with a volume of 700 cu. ft of which only 35 cu. ft is occupied by heavy water during normal operation. Electric pressurizing heaters are installed outside the pressurizer vessel as a separate steam generator because of heavy water economy and to protect the heaters in the event of a sudden loss of water from the pressurizers. The operating pressure of 480 p.s.i.a. is controlled by means of a constant spray flow of 1 lb/sec taken from the reactor inlet flow at a temperature of 400-420°F and this is balanced by a continuously controlled group of heaters (100 kW) actuated by the pressurizer steam pressure. The cooling effect of the spray will be 50-70 kW.

The primary system contains about 70 tons of heavy water and will have a total stainless steel surface of 30,000 sq. ft in the first stage and 50,000 sq. ft in the second. The purification flow is normally 8.5 lb/sec but can be increased to 11 lb/sec. There are three mixed bed ion exchangers, one for normal flow and two for maximum. Bled from the main circuits the pressure is increased from 500 to 580 p.s.i.a.; the water passes through the regenerative heat exchangers where it is cooled down from 410°F to 122°F and then enters the demineralization columns.

Waste gases from the D_2O systems are stored in four gas tanks, 360 cu. ft each and designed for 150 p.s.i.g. The gas is scrubbed and diluted 1,000 times in the chimney stack before being allowed to escape.

MAIN CONTRACTORS

ALLMANNA SVENSKA ELEKTRISKA AKTIEBOLAGET (ASEA), Vasteras.
Main Contractor.
UDDEHOLMS AB AND DEGERFORS JENVERK AB, Degerfors.
Reactor vessel.
NYDQVIST AND HOLM AB, Trollhattan.
Charge machine.
AB ROSENBLADS PATENTER, Stockholm and Jönköping, and MEKANISKA WERKSTADS AB, Jönköping.
Main heat exchanger.
DE LAVAL LJUNGSTROM PUMP AB, subcontractor Hayward Tyler, U.K.
Pumps for the primary cooling system.
AB NORDISKA ARMATURFABRIKERNA, Linköping.
Valves for the primary cooling system.
NORDISKA VARME AND VENTILATIONS AB, Goteborg, in connection with NAUMBURGS INDUSTRI AB, Stockholm. AVESTA JERNVERKS, AB, Avesta.
Tube parts, design and construction of the tubes for the primary cooling system.



One of the two flanges separating the top of the R3/Adam reactor from the vessel.

FINNISH POWER POSITION

WITH an electrical production 90% reliant upon hydro-power and with the prospect of reserves of additional sources being exhausted by 1970, Finland is facing a serious shortage of power. All fossil fuels are imported and these already account for 14-18% of the total value of imports to the country. Although certain advances are being made in connection with peat burning power stations it is estimated that only a small part of the future demand can be met by domestic fuels (including firewood and industrial wastes).

Energy Position

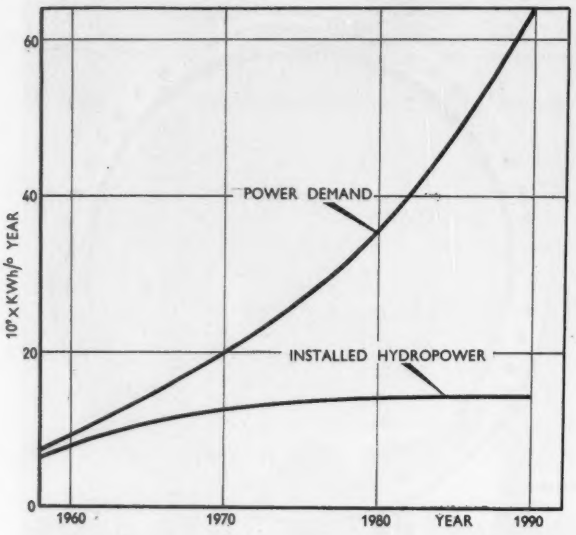
A substantial change has taken place since 1951 when the total consumption amounted to 10.0 million tons of coal equivalent of which hydro-power accounted for19%, imported fuels nearly 30% and domestic fuels 50%. Imported fuels then amounted to 12.1% of the total volume of imports.

In 1957 domestic fuels accounted for 40%, hydro-power 23% and imported fuels 37% making a total consumption of 13.8 million tons of coal equivalent. Imported fuels were then nearly 18% of total imports. In 1958 hydro-power accounted for 88% of the generated power but already it was considered that the near optimum point had been reached for the importation of fossil fuels. The total hydro-power resources will be exhausted in about 15 years time but the time scale for economical utilization is 10 years or less.

In 1957 the increased demand for energy had exceeded the estimates prepared by an Energy Committee in 1955 and there is no reason to presume that this growth should substantially slow down. The increase in demand at the moment is 10.5% per year, one of the highest in Western Europe. An interesting comparison is that in the period 1948-58 the Finnish demand multiplied by 2.5 whilst Sweden's doubled. The estimate of the demand for energy in the 1960-65 period shows that the volume of imported fuels would have to double (nearly 30% of total imports) whereas 20% is calculated to be the maximum fraction that the country can support. To retain this position, the total volume of imports and exports would have to double.

The Advisory Commission for Industrialization in its report on the energy situation, published last year, concludes that although Finland has managed to maintain a sufficient supply of energy to date, the situation will be impossible to handle in the next few years without decisive and urgent measures.

These facts are now being faced by industry and State alike and the first stage in building for a nuclear power future has been embarked upon. The Institution of Technical Physics in the Institute of Technology, who are responsible for nuclear research, have purchased a Triga II reactor and will shortly commence building a critical facility (having already constructed a sub-critical one); arrangements have been made with the IAEA for the supply of a limited amount of enriched fuel for these



This graph shows the rapidly rising power demand in comparison to the installed hydropower capacity which begins to level out soon after 1970.

reactors. At the request of the Finnish Atomic Energy Commission, at present a small administrative section only, within the Ministry of Commerce and Industry, the IAEA is assisting in a survey of the nuclear potential and appear to be reaching similar conclusions to those of a committee set up in 1955 in Finland. This committee submitted their findings in the same year and the most salient feature was that an intensive training programme had to be undertaken before a positive construction programme could be considered. This training programme could be made more realistic by an increased budget, which has yet to materialize.

In Finland the State produces 40% and private industry 60% of the electrical output, but the integration of load centres is poor and the installation of large blocks of power will require extensive organization. No plans for a nuclear power station have been formulated yet but the basically State owned power company, Imatran Voima, are making preliminary studies in conjunction with the Atomic Energy Commission. This company is also undertaking an intensive research programme in connection with uranium deposits and although no figures are yet available, the reserves are expected to be large. Atomienergia has just started uranium concentrate production in Paukkajanvaara, most of which is being exported to Sweden. Because of the uranium situation the Finnish nuclear programme is expected to be based upon natural uranium fuels.

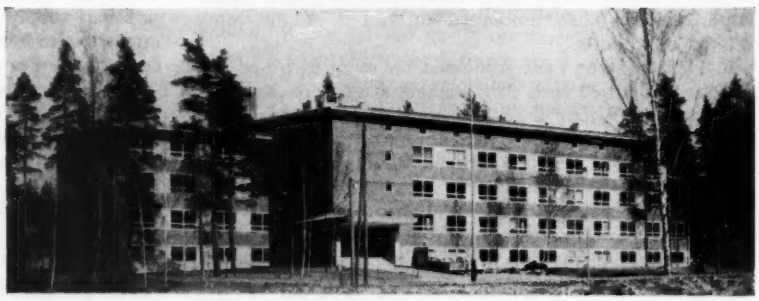
Within the Ekono organization (a body formed by industry to act in an advisory capacity) is the Nuclear Power Association Ydin, who have surveyed the power demand position. This organization has estimated that the possibilities of nuclear power becoming competitive in Finland at a relatively early date are strong owing to the higher cost of thermal and hydro power. Should oil prices show even a gentle upward trend, nuclear power could be competitive in the middle 1960s. Oil is at the second lowest price level in Finland since 1950 and the peak prices reached during the Korean and Suez periods caused generation costs to rise well above the figure estimated for nuclear generation.

The majority of coal imports are from Poland and the possibilities of large-scale imports of oil from the Russian Ural reserves may offer keen competition but the lack of storage facilities and a strong national desire to remain as independent as possible are arguments on the side of installing nuclear power stations.

The geographical situation of Finland and the national character of the people are important factors in a general understanding of the industrial position. Finns are traditionally independent. They have managed to keep a balance between East and West trade and also a balanced neutral position in world affairs. That they should remain in this position is considered vital. The peace-treaty signed with the Allies at the end of the last World War prevented them from pursuing any nuclear investigations until 1955 and this late start has resulted in a serious shortage of nuclear scientists. Nevertheless the coming power shortage should be enough to stimulate a rapid entry into the nuclear field and the possibilities of a nuclear power station being started upon within the next two years are extremely strong. It would be in the order of 200 MW to be in full operation by 1970 and tentative plans foresee one similar station being built each year from then on.

Nuclear ship propulsion also is being given active consideration. Finland has the largest ice-breaker-building shipyard in the world, Wartsila-Koncernen A/B. This concern export the majority of their output to Russia however, which introduces a nice complication. The chances of them importing an American reactor for installation in an ice-breaker destined to join the Russian fleet do not appear to be feasible at the moment, but there is a feeling that a reactor originating in Britain or Sweden could be acceptable. Unless Finland can continue to compete in ice-breaker manufacture one of her most important industries would be threatened.

The contributions that Finnish industry can make to the land programmes should not be underestimated. Although its nuclear experience is small, with a background of conventional power station construction it is instituting training programmes which will allow it to participate energetically in all but the most sophisticated operations of reactor construction when the time comes.



The new Institute of Technology research building, where the critical facility will be built and the Triga II housed, is situated several miles out of Helsinki.

Electric furnace steel forgings supplied by Beardmore were used in the construction of the Berkeley reactor pressure vessels.

Electric Furnace Steel *for Nuclear Applications*

Steel produced in the electric arc furnace has improved mechanical properties compared with that manufactured by the open hearth process. No long term data are yet available on the creep properties of C/Mn steel.

By C. JAMIESON, A.R.C.S.T.
and J. MOWAT, B.Sc., F.I.M.
Director of research, Wm. Beardmore & Co., Ltd.

THE steel components of reactor pressure vessels, both plates and forgings, are subjected to the most stringent acceptance tests prior to assembly: the steel must be free from internal defects, and also have satisfactory physical properties with particular emphasis on a low impact transition temperature. At present the steel used for fabrication of pressure vessels is C/Mn steel with an ultimate tensile strength in the range 28-32 ton/in.^{2} and made almost entirely in acid or basic open hearth furnaces. It is now fairly evident that an improvement in quality would be obtained, both from the point of view of cleanliness and physical properties, if steel from the basic electric arc furnace were used rather than that made by the open hearth process.

Before any decision can be made regarding the relative improvement in quality of electric furnace steel it will be necessary to investigate thoroughly a large number of production casts, for only in this way can a representative survey of the properties be obtained. Such a programme is at present under way, using C/Mn steel, but it will be some time before all the results can be obtained. However, as one of the main features of interest is the mechanical properties obtainable, and particularly impact properties, the results shown in this paper will give some indication of the test values which can be expected.

Before considering the properties of electrical furnace steel it is necessary to recall the basic features of the steelmaking process to gain some idea of the reasons for the characteristic features of this class of steel. The basic electric arc furnace process of steelmaking is essentially a double slag or two-stage process, using an almost 100% scrap charge with just sufficient carbon or pig iron added to enable the charge to be worked after melting. The charge is initially melted and refined under oxidizing conditions during which period oxidizable elements such as carbon, phosphorus, silicon, etc., are removed from the metal: the bulk of the oxidation is effected by oxygen injection. When oxidation is complete the slag is removed and replaced by a strongly reducing slag the purpose of which is to reduce the oxides in the bath, and also to remove sulphur from the metal. The reducing character of the slag and the absence of oxidizing gases is a condition attained only in the basic electric furnace and is in contrast to the open hearth process where gases and slag are oxidizing at all times.

As the reducing slag decreases the oxygen content of the bath to a low value, relatively few deoxidation products are formed when the final deoxidizers are added to the bath because less of the latter are needed: also, the deoxidation products that are formed can rise through the bath and enter the slag more easily than would similar products formed by adding large amounts of deoxidizers to the ladle, which is normal basic open hearth practice. As a result, relatively few sulphide and oxide inclusions are present in electric furnace steel. Close control of tapping temperatures and furnace conditions can be obtained which

enables the conditions to be reproducible with several different casts of identical material.

Mechanical Properties:

Forgings. All electric furnace steel at present being made for reactor pressure vessel forgings is classed as silicon killed C/Mn steel with aluminium added to control the grain size and stabilize the nitrogen present. The aluminium is usually added to the ladle after the metal has been thoroughly deoxidized with silicon and the amount added can vary between 8 oz/ton and 2½ lb/ton depending on such variables as chemical composition, amount of mechanical working, heat treated size of the forgings, and specification requirements. The specification often limits the aluminium addition which may be made to the charge but in any case the amount added should never be more than the minimum necessary to ensure satisfactory results. The aluminium addition is limited because of its adverse effect on creep properties and possible effect on graphitization, but this must always be considered from the point of view of the ultimate service conditions of the steel: in many instances the high temperature properties are not critical. However, rather than specifying a maximum aluminium addition in lb/ton, it would be more realistic to limit the total residual aluminium content of the steel.

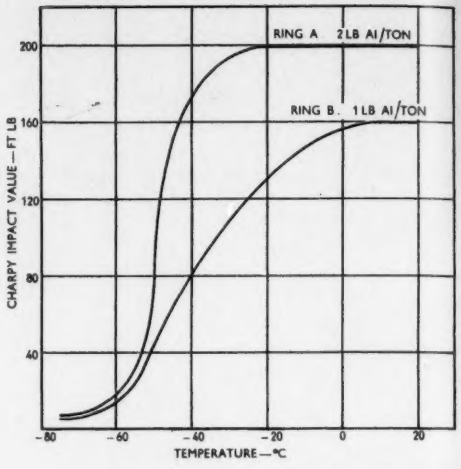


Fig. 1.—Charpy transition curves for hollow forged rings, C/Mn electric furnace steel normalized and tempered. Forged size of rings 93 in. o.d. by 63 in. i.d. by 35 in. Test position: Ring A, tangential 7 in. below surface; Ring B, tangential 1 in. below surface.

TABLE 1

Solid forged discs: 3 ft×8 in. (debris removal nozzles). Heat treatment: normalized. Al. addition: 1½ lb/ton. Circumferential tests.

JOB No.	ANALYSIS C.	Mn.	Si.	S.	P.	Y.S. T/in.²	U.T.S. T/in.²	El. on 4√A	R.A. %	Charpy impact value at −10°C. ft lb		
18239	.16	1.04	.23	.014	.012	22.8	31.2	40.0	71.8	93	125	97
18220	.15	1.03	.27	.015	.015	22.0	30.8	40.0	67.8	109	79	102
18216	.15	1.04	.23	.014	.012	22.0	31.2	39.0	69.8	120	135	89
18212	.15	1.03	.26	.015	.015	22.0	31.2	39.0	69.8	102	92	100
18224	.17	1.03	.27	.013	.016	22.8	32.8	38.0	65.8	94	94	100
18217	.16	1.09	.21	.015	.011	22.8	31.2	39.0	69.8	94	78	115
18214	.16	1.03	.21	.015	.012	22.4	30.8	39.0	67.8	75	100	92
18210	.16	1.07	.21	.015	.012	21.6	30.8	40.0	69.8	101	108	87

The property of most importance from the mechanical test point of view is the degree of notch ductility or transition temperature of the steel. For routine quality control purposes the acceptance limit for Charpy V-notch impact value is usually taken to be a minimum of 20 ft lb, and in some cases 35 ft lb, at −10°C. These values have been in existence for some time, and it is possible that if electric furnace steel shows evidence of consistently giving higher values the acceptance limits may be increased, with a consequent increase in the safety factor in reactor vessel design.

Typical compositions and mechanical properties of various types of forgings taken from official test results, are given in tables 1-4. Points worthy of note are the consistently low sulphur and phosphorus values, the high level of ductility as measured by the elongation and reduction of area figures, and the Charpy impact values which are well above specification requirements. The normal specification limits of 0.04% max. for sulphur and phosphorus contents could be lowered to 0.02% max. when using electric furnace steel. The ductility values obtained from tensile tests, although having no directly applicable design significance, are useful in that they give some indication of the ability of the steel to withstand a reasonable amount of plastic deformation before fracture.

When steel is subjected to irradiation these values are reduced, and it is advisable to start with the highest ductility values possible. This consideration also applies to transition temperature which can be raised to an appreciable degree by irradiation, and should therefore be as low as possible before entering service. There is some evidence to suggest[1] that high purity steel, i.e. steel with low sulphur and phosphorus contents, is less susceptible to irradiation embrittlement than steel with high sulphur and phosphorus contents, a point in favour of electric furnace steel. Charpy V-notch transition curves for large ring forgings made with differing aluminium additions are shown in Fig. 1. The effect of the additional 1 lb of aluminium/ton is probably slightly greater than is shown by the curves, since the test material from ring "B" with 1 lb of aluminium/ton added was cooled considerably faster from the normalizing temperature than the test material from ring "A" which was 7 in. beneath the surface.

Plates: Some time ago Beardmore's supplied a large number of 3-in. thick C/Mn steel plates which were used for the construction of a reactor pressure vessel. The plates were made both by the acid open hearth process

TABLE 2

Solid forged bars: 32 in.×11 ft (stand pipe flanges). Heat treatment: normalized. Al. addition: 1½ lb/ton. Longitudinal tests.

JOB No.	ANALYSIS C.	Mn.	Si.	S.	P.	Y.S. T/in.²	U.T.S. T/in.²	El. on 4√A	R.A. %	Charpy impact value at −10°C. ft lb		
18237	.14	1.05	.20	.011	.015	19.2	29.6	40.0	73.5	117	188	133
18246	.14	1.05	.20	.011	.015	18.8	29.6	39.0	73.5	93	116	109
18247	.13	1.01	.19	.015	.020	19.2	30.0	39.0	71.8	80	103	104
18257	.13	1.01	.19	.015	.020	18.8	30.0	39.0	71.8	109	116	118
18258	.12	1.10	.23	.018	.018	18.0	28.8	40.0	73.5	194	194	170
18268	.12	1.10	.23	.018	.018	17.6	28.8	40.0	71.8	162	165	165
19231	.11	1.45	.20	.008	.013	20.4	32.0	39.0	75.4	118	132	119
18681	.12	1.53	.33	.008	.010	22.8	30.8	41.0	77.2	215	216	197

and the basic electric arc process, and thus a good opportunity was afforded for a comparative study of results. The most significant difference in the properties of the two classes of steel was in the impact values obtained. A summary of these is reproduced in table 5. Steel made in the basic electric arc furnace gives a larger percentage of impact values in the higher ranges. These plates were made without the benefit of aluminium addition but present day specifications allow aluminium to be added to a maximum of 8 oz/ton. In order to determine the effect of increasing aluminium additions on the physical properties of electric furnace steel, four full size 3-in. thick plates were made, with aluminium additions ranging from nil to 2 lb/ton. The plates were extensively tested in the normalized condition and also after receiving the stress relieving treatment recommended by the U.K. AEA, i.e., 36 hours at 600°C. with controlled cooling to 250°C. The chemical composition and mechanical properties of the plates are given in tables 6 and 7. All test results shown are taken from the plates in the normalized condition.

Charpy V-notch impact tests were taken at T/3 and 2T/3 levels from six positions on each plate, i.e., the four corners and the mid-ends of each plate, and the results are shown in table 8. There is a considerable scatter of impact values obtained with plate No. 8062 which did not have aluminium added to it: this tendency to give a wide scatter of results has been shown by other plates made without aluminium addition, and is probably due to the test temperature being in the region of the transition temperature. This effect can be reduced by the addition of 8 oz aluminium/ton to the ladle. Charpy V-notch transition curves for material from the bottom end centre position are given in Figs. 2 and 3. Similar tests are being carried out on the plates in the stress relieved condition which is the ultimate service condition of the plate, and results at present available show a slight decrease in transition temperature using both impact energy and fracture appearance criteria. A programme of Robertson crack arrest tests and Pellini drop weight tests was undertaken in order to supply similar information to that already existing for open hearth steel plates, and this information is given in table 9.

The extent to which C/Mn steel plates can be used for future reactors is limited and it is probable that this composition will be replaced in certain applications by a low-alloy steel which would have higher yield and ultimate strengths, with good notch ductility and high temperature properties. Such steels must be readily weldable. An example of the mechanical properties which may be expected from low-alloy steel plates in the normalized and tempered condition is given in table 10. The plate thickness in all cases is 5 in. with transverse tensile tests and longitudinal Charpy V-notch tests taken from the mid-thickness of the plates, from both ends. The scatter in the Charpy V-notch results is due to the test temperature being within the transition range: this steel is a semi-air hardening composition and the rate of cooling at the centre of the plate is not sufficient to give a homogeneous low-temperature transformation product, and results in a mixed microstructure of ferrite, pearlite and bainite. The impact results will be improved by taking the tests other than at mid-thickness and also by the air cooling which the plates receive after pressing, which is virtually a double normalizing treatment. Low-alloy plates such as these can be pressed, welded, then stress relieved, i.e., there is no need for an intermediate tempering treatment. Ideally, these plates should be quenched and tempered to give the best mechanical properties, but this introduces fabrication

TABLE 4

Hollow forged rings: 93 in. o.d.×63 in. i.d.×35 in. (gas inlet and outlet conns.). Heat treatment: norm. and temp. Al. addition: 2 lb/ton. Circumferential tests.

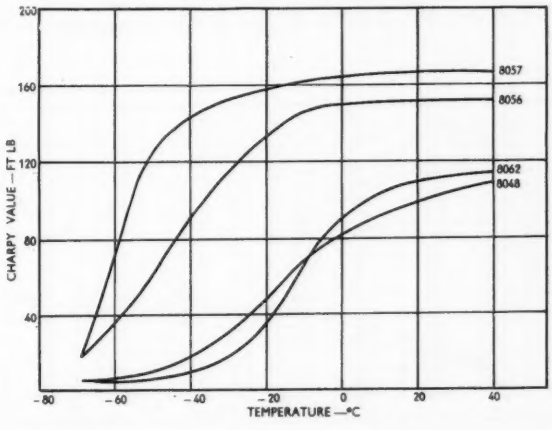
JOB No.	ANALYSIS C.	Mn.	Si.	S.	P.	Posn.	Y.S. T/in.²	U.T.S. T/in.²	El. on $4\sqrt{A}$	R.A. %	Charpy impact value at −10°C. ft lb		
18515	.12	1.40	.26	.010	.010	T.E.	20.4	28.4	42.0	75.4	216	216	216
						B.E.	20.0	28.8	40.0	77.2	217	217	217
18516	.11	1.54	.29	.009	.014	T.E.	20.8	30.0	41.0	75.4	162	156	161
						B.E.	22.0	30.0	40.0	73.5	174	85	142
18517	.12	1.55	.31	.011	.018	T.E.	19.6	29.2	40.0	75.4	217	217	217
						B.E.	19.2	28.4	40.0	75.4	217	217	217
18518	.15	1.41	.23	.010	.015	T.E.	18.8	30.8	40.0	73.5	170	95	153
						B.E.	20.0	30.0	40.0	75.4	197	217	217
18519	.10	1.40	.24	.011	.015	T.E.	19.6	28.8	41.0	78.8	217	191	217
						B.E.	19.2	28.8	40.0	77.2	217	155	188
18520	.11	1.56	.31	.010	.012	T.E.	20.4	29.6	40.0	75.4	195	212	187
						B.E.	20.8	30.0	40.0	75.4	217	200	217
18521	.13	1.43	.27	.010	.012	T.E.	19.6	29.6	41.0	77.2	207	195	194
						B.E.	19.2	28.4	41.0	77.2	217	185	217
18522	.13	1.42	.19	.009	.016	T.E.	20.0	28.8	41.0	77.2	166	190	182
						B.E.	19.6	28.8	41.0	75.4	184	177	204

TABLE 3

Hollow forged nozzles: 29 in. o.d.×17 in. i.d.×9½ in. (burst slug detection nozzles). Heat treatment: norm. and temp. Al. addition: 1 lb/ton. Circumferential tests.

JOB No.	ANALYSIS C.	Mn.	Si.	S.	P.	Y.S. T/in².	U.T.S. T/in.²	El. on $4\sqrt{A}$	R.A. %	Charpy impact value at −10°C. ft lb		
18539	.09	1.50	.25	.010	.010	18.8	28.4	41.0	75.4	162	170	174
18541	.10	1.44	.19	.012	.012	19.2	28.4	40.0	75.4	115	100	151
18542	.10	1.49	.17	.011	.013	18.0	28.4	40.0	75.4	92	88	109
18544	.10	1.49	.17	.011	.013	18.8	28.4	41.0	75.4	88	90	79
18545	.09	1.50	.25	.010	.010	20.4	28.0	41.0	78.8	135	166	174
18547	.10	1.47	.35	.010	.010	19.2	28.0	41.0	75.4	110	105	96
18548	.11	1.50	.17	.011	.012	18.8	28.4	40.0	73.5	100	48	65
18550	.11	1.50	.17	.011	.013	18.0	28.4	38.0	65.8	109	87	76

Fig. 2.—Charpy transition curves showing effect of aluminium. C/Mn electric furnace steel, normalized; plate size 25 ft by 8 ft by 3 in. Test position: Bottom end of plate; longitudinal tests at T/3 level. Plate No. 8062, no Al added; 8048, 8 oz Al/ton; 8056, 1 lb Al/ton; 8057, 2 lb Al/ton.



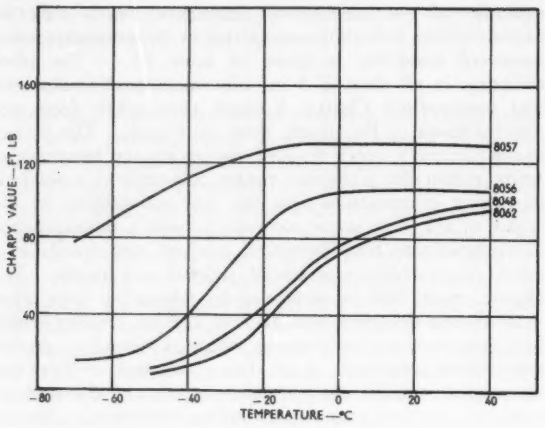


Fig. 3.—Charpy transition curves showing effect of aluminium. C/Mn electric furnace steel, normalized. Plate size: 25 ft by 8 ft by 3 in. Test position: Bottom end of plate. Transverse tests at T/3 level. Plate No. 8062, no Al added; 8048, 8 oz. addition; 8056, 1 lb Al/ton; 8057, 2 lb Al/ton.

difficulties due to pressing having either to be done at temperatures below the tempering temperature, with the attendant springback difficulties, or else die-quenched to shape and then tempered. There may also be difficulty in obtaining suitable electrodes to ensure that the properties of the weld metal are equal to the properties of the parent plate. Experimental results with plates of this composition in the quench and tempered condition indicate that 40 ton/in.² minimum U.T.S. and consistent Charpy V-notch values of 100 ft lb at −10°C will be obtained.

Creep Properties

The determination of creep design data involves testing to very long times and as yet no long term data is available on basic electric arc furnace C/Mn, steel. A full scale programme, however, is being put into operation on plate No. 8048 and this is expected to give the necessary information. This programme involves creep tests at 400°, 425°, 450° and 475°C, four stresses at each temperature designed to give 0.2% creep strain in times between 100 and 20,000 hours. Rupture tests are also being carried out at 375°, 400° and 425°C, five stresses at each temperaure designed to give rupture in times between 100 and 20,000 hours.

A smaller programme is being carried out on steel from plate No. 8056. This involves creep tests at 375°, 400°, 425°, and 450°C, at a stress of 7 ton/in.² and is intended to show the effect of the higher aluminium addition on the creep properties.

Fig. 4 shows some early creep tests carried out on the four plates. These tests were carried out at a stress and temperature similar to service conditions, i.e., 7 ton/in.² at 345°C. There is little difference between the steels, the results being within the scatter band one would expect from four similar steels. This is probably due to the low conditions of testing; no doubt the higher temperatures in the full-scale programme will prove to be more

TABLE 5

Summary of impact values obtained from plates used in a reactor pressure vessel. Tested after pressing prior to fabrication.

MANUFACTURING PROCESS	TOTAL No. OF TESTS	PERCENTAGES OF VALUES IN THE RANGES:—			
		Below 30 ft lb	30–40 ft lb	40–50 ft lb	Over 50 ft lb
Acid open hearth	476	22.8	31.5	21.18	23.9
Basic elect. arc	475	15.1	22.7	27.3	34.9

TABLE 6

Chemical composition of plates 8062, 8048, 8056 and 8057

PLATE No.	ALUMINIUM ADDITION	C.	Mn.	Si.	S.	P.	Ni.	Cr.	Mo.	Aluminium	
										Sol.	Total
8062	Nil	.13	1.37	.30	.010	.013	.12	.11	.04	—	—
8048	8 oz/ton	.13	1.35	.19	.011	.015	.15	.11	.02	—	.007
8056	1 lb/ton	.15	1.29	.30	.010	.012	.13	.14	.03	.007	.012
8057	2 lb/ton	.14	1.34	.27	.009	.014	.13	.11	.03	.025	.031

TABLE 7

Mechanical properties of plates 8062, 8048, 8056 and 8057

PLATE No.	ALUMINIUM ADDITION	Posn.	Y.S. Tons/in.²	U.T.S. Tons/in.²	El. on $4\sqrt{A}$	R. of A. %	BEND
8062	Nil	T.E.	21.6	33.6	37.0	71.8	180°
		B.E.	20.4	30.4	39.0	69.8	180°
8048	8 oz/ton	T.E.	22.8	33.2	37.0	69.8	180°
		B.E.	21.6	32.0	36.0	65.8	180°
8056	1 lb/ton	T.E.	24.8	33.6	43.0	67.8	180°
		B.E.	24.0	32.8	37.0	65.8	180°
8057	2 lb/ton	T.E.	25.2	32.8	38.0	73.5	180°
		B.E.	22.8	31.6	40.0	75.4	180°

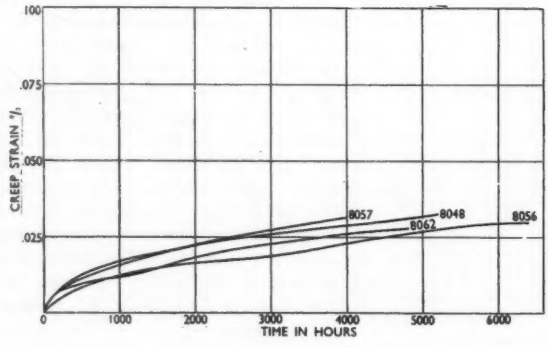


Fig. 4.—Creep analysis of C/Mn electric furnace steel. Stress: 7 ton/in². Temperature 345°C. Plate No. 8062, no Al added; 8048, 8 oz/ton; 8056, 1 lb/ton; 80571, 2 lb/ton,

TABLE 8

Showing variation of Charpy impact results from different positions in plates 8062, 8048, 8056 and 8057. Test temperature: −10°C.

Top end corners: A, C. Top end centre: B. Bottom end corners: D, F. Bottom end centre: E. Longitudinal tests: L1—one third through plate thickness. L2—two thirds through plate thickness.

PLATE No.		ALUMINIUM ADDITION	POSITION					
			A	B	C	D	E	F
8062	L1	Nil	75 68	27 14 47 89	60 75	20 17	69 71	43 50
	L2		77 71	62 23 45 28	75 100	45 22	— —	62 62
8048	L1	8 oz/ton ..	83 45	76 78	67 58	85 82	61 56	90 60
	L2		66 40	86 88	47 45	88 62	— —	83 57
8056	L1	1 lb/ton ..	146 135	104 85	140 136	130 125	163 156	90 60
	L2		149 142	63 63	139 120	127 111	— —	83 57
8057	L1	2 lb/ton ..	208 201	193 175	213 212	216 216	215 202	212 164
	L2		216 195	216 207	216 200	215 205	— —	206 165

TABLE 9

PLATE No.	CONDITION	ROBERTSON GRADIENT	DROP WEIGHT—N.D.T.
8062	Normalized	− 9°C.	0°C.
8048	Normalized	−15°C.	0°C.
8052	Stress relieved, 36 hours at 600°C.	−25°C.	− 5°C.
8048	Stress relieved, 36 hours at 600°C.	−26°C.	−10°C.

discriminating although this has yet to be demonstrated. Unfortunately, the collection of creep data is a long and tiresome task and cannot be hurried.

Residuals

Due to the fact that the electric furnace works on a 100% scrap charge the residual content of the steel produced tends to be higher than the value for open hearth steel. In the electric furnace oxidizable residuals such as chromium can be largely removed during the first stage of the process but virtually nothing can be done to remove such elements as nickel and copper. In the open hearth process the total percentage of these elements is much smaller due to dilution of the charge with large amounts of pig iron. A recent specification for forgings to be used in a nuclear power station sets the individual residual limitations as follows:—

Ni 0.25 max., Cr 0.20 max., Mo 0.10 max., Cu 0.15 max.

The sum of the residuals must not exceed 0.55%.

A limitation on the total amount of residuals is necessary from the point of view of weldability, but it is unlikely that the small amount of residuals inherent in electric furnace C/Mn steel will adversely affect the otherwise excellent weldability of this steel. This question can only be satisfactorily resolved by carrying out a series of weldability tests on material from a number of different casts of electric furnace steel.

Nitrogen Content of Electric Furnace Steel

In the electric furnace there is a tendency for nitrogen absorption by the steel due to fixation of nitrogen in the electric arc, and the nitrogen content of electric furnace steel is usually slightly higher than open hearth steel, and as a result may be more susceptible to strain age embrittlement. Impact resistance, and particularly transition temperature, is adversely affected by this phenomenon. In a recent paper[2] it has been estimated that as much as 20°C rise in transition temperature due to ageing may take place, all largely within the first two years of operation: this figure is based on the use of open hearth steel plates. Similar tests are at present being carried out by several different organizations to obtain comparable data on electric furnace steel. However, all electric furnace steel at present being manufactured for use in nuclear power stations is silicon killed with aluminium added as a grain controlling agent. The final silicon content of this steel is usually 0.2-0.3%: the steel is thus not only thoroughly deoxidized with silicon which alone would reduce the strain ageing characteristics, but also the addition of aluminium will promote the formation of the stable nitride, AlN, which should largely negate the strain ageing tendency.

Conclusions

It is too early as yet to have obtained all the necessary information on electric furnace steel, particularly the creep information, and this article is only intended to highlight the type of information which is required. Large testing programmes on electric furnace steel are at present being carried out by the U.K. AEA, CEGB and by various other interested groups, and it should not be long before a much more complete picture is obtained.

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(2) Kehoe and Nichols, U.K. AEA I.G. Report 146 (RD/C).

TABLE 10

Mechanical properties of 5-in. thick low alloy steel plates

PLATE No.	ANALYSIS									Posn.	Y.S. T/in.²	U.T.S. T/in.²	El. on $5.65\sqrt{A}$	R.A. %	Charpy value at −10°C. ft lb		
	C.	Mn.	Si.	S.	P.	Ni.	Cr.	Mo.	V.								
8090	.14	1.40	.20	.019	.018	.18	.60	.31	.07	T.E.	29.4	35.8	28.0	60.8	26	39	21
										B.E.	27.0	34.2	29.0	62.4	53	35	42
8091	.12	1.47	.20	.012	.010	.17	.62	.27	.51	T.E.	28.6	35.0	30.0	66.8	39	69	44
										B.E.	27.0	34.0	29.0	65.4	118	91	137
8146	.12	1.41	.27	.012	.013	.16	.57	.26	.08	T.E.	28.6	34.4	30.0	72.4	71	101	25
										B.E.	28.0	34.0	30.0	72.4	105	115	120
8154	.12	1.30	.26	.011	.015	.20	.53	.27	.07	T.E.	27.4	35.2	30.0	71.0	42	69	55
										B.E.	27.6	34.4	30.0	72.0	62	51	60
8157	.12	1.36	.24	.009	.015	.20	.58	.25	.07	T.E.	28.6	34.0	30.0	72.4	74	37	65
										B.E.	28.0	34.2	31.0	73.6	130	92	140
8158	.14	1.29	.125	.013	.013	.23	.63	.25	.07	T.E.	29.0	34.2	31.0	72.4	67	30	78
										B.E.	29.2	35.0	29.0	72.4	33	25	58
8147	.12	1.33	.26	.011	.010	.13	.45	.28	.09	T.E.	25.8	34.0	31.0	66.8	38	112	108
										B.E.	27.0	34.8	31.0	68.2	50	67	22
8177	.10	1.39	.35	.015	.015	.16	.53	.26	.07	T.E.	26.4	34.0	32.0	69.6	65	28	22
										B.E.	26.6	34.2	32.0	69.6	104	132	149

ELECTRIC STEEL MELTING

Production and Economic Aspects

By J. E. RUSSELL, M.A., F.I.M.
(*Superintendent, English Steel Corporation Group Research Laboratories.*)

The electric melting of steel, referred to in the previous article, is here discussed from the economic aspect.

THE use of electric power for steel melting on a production scale dates from about the beginning of the present century. A number of different types of furnace have been developed, which either melt the charge by induction heating or by the heat from an electric arc, but over the past 40 years certain particular designs have evolved, each of which has proved to be the most efficient for particular purposes. High-frequency furnaces are now used almost exclusively for relatively small-capacity units producing special grades of high alloy steel. The electric arc furnace, to which this article is confined, is the one used for production on a large scale.

Over the first quarter of the century, the output of electric furnace steel in Britain did not increase rapidly, but valuable experience was accumulating so that when rearmament commenced in about 1935-36, the production was able to be rapidly expanded, as shown in Fig. 1. After the war output dropped, as did the whole national steel production, but in a review of steelmaking in 1947 J. M. Mowat[1] was able to report an extremely favourable competitive position for electric steel as compared with open-hearth. Since then, production has risen gradually, with small periodic halts which are probably all due to the political uncertainty associated with general elections and not to any technical consideration.

All arc furnaces of any size are basic-lined, and the steelmaking method resembles basic open-hearth practice, which reduces the phosphorus in the steel, but an extra process is usually added whereby the melting slag is removed and replaced by one which reduces the sulphur content of the bath. Thus, both sulphur and phosphorus contents can be reduced to very low levels—0.015% maximum is very common. However, a "single slag" method is being used more and more, even though the sulphur may remain relatively high, as in normal basic open-hearth working, in order to achieve some of the very significant economies offered by the electric process as compared with others. The quality of electrically-made steel is very high, the double slag product being generally much cleaner than open-hearth steel and tending towards a finer grain-size without any additions of aluminium or of other elements often used for controlling the grain-size.

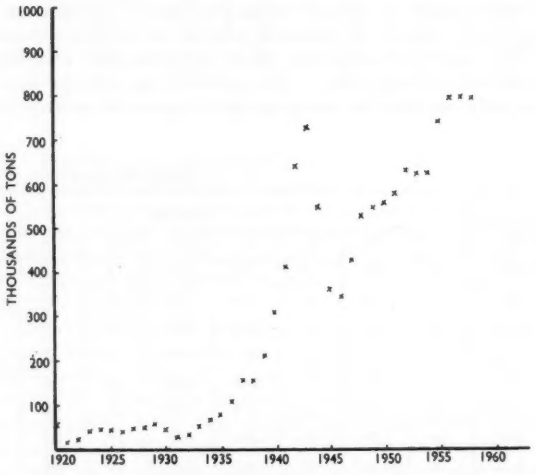

Fig. 1.—Electric furnace steel production in Great Britain.

The associated article by Mr. Mowat goes more deeply into this point.

Advantages

The main advantages of the electric arc process are:—

(1) Relatively low capital cost.

(2) Low maintenance costs.

(3) High rate of output, and

(4) Ability to use large amounts of scrap.

It is generally accepted that the "investment cost per ingot-ton for electric furnaces is about 50% less than that of a comparable tonnage open-hearth shop"[2]. This is quoted from an American source, but is confirmed by later studies[3]. This is partly due to the electric furnace being generally much more compact than the open-hearth with no checkers or gas-producers. Except when very large forging ingots are being produced, an output equivalent to that of a large open-hearth plant can be obtained from smaller electric furnaces with consequent advantages; the associated craneage and pit-side facilities need not be so heavy, and since the tap-to-tap time is relatively short the output is presented for handling generally in smaller lots, but more frequently, than in an open-hearth plant.

Because of the general simplicity of construction, maintenance costs per ton of output are usually fairly low. The production rate is extremely high as compared with open-hearth melting, the output on "two-slag" working being from 4 tons per hour from small units, to 12 tons per hour in large furnaces. When Mr. Mowat made his survey in 1947, to which reference has already been made, he concluded that the electric furnace would probably never compete with the "bulk steel" producers using hot metal in large basic open-hearth furnaces, but the process is rapidly catching up even here. Using the single-slag process, on large furnaces of over 100 tons capacity (the largest at present in existence is 180 tons) an output-rate of the order of 30 tons per hour can be regularly achieved on plain carbon steels[2], and up to 15 tons per hour for high alloy steels. In America and on the Continent[4] these large furnaces are already competitive with the basic open-hearth "bulk" shops.

The electric furnace at the moment uses considerable proportions of scrap in the charge, usually about 95% as compared with 23-50% for a hot-metal open-hearth, or about 73% for a cold-metal one[5]. Indeed, over the past six years the scrap used in the electric furnace has been over 101% of the steel produced[1]. On the other hand, the yield of good steel actually cast is the highest of all processes—in 1958 the average over the whole country was 96%. This ability to use large amounts of scrap was formerly an economic advantage, but more recently the rising prices of scrap and more efficient blast furnace practice, which has cheapened pig iron, has reduced the advantage considerably.

Hydrogen Content

Among objections occasionally urged against the arc melting process are the high cost of electricity, and the high hydrogen content which the process tends to produce in the steel. The latter objection mainly applies to the two-slag process, in which the hydrogen content is reduced to very low levels during the boiling down period under the first slag, but increases again during the period under the second slag. The exact reason for this is not clear, although many causes have been suggested, such as humidity of the atmosphere, moisture in additions, slag materials, etc., but evidence from one source continually meets contradicting evidence elsewhere, and the picture is by no means clear. The single-slag process tends to be lower in hydrogen because the second period is omitted, but any delay between the boil-down and tap may mean rising hydrogen, and delays can occur through purely external reasons, e.g., difficulty of receiving analysis results in reasonable time.

However, this hydrogen difficulty will almost certainly be overcome in this country in the very near future by ladle degassing or by vacuum casting of the ingot itself. Hydrogen is rapidly extracted by these means and quite low levels are easiiy achieved. There is evidence also that a cleaner steel is obtained. Steel cast in this manner should exceed in quality any that is available from commercial furnaces at the present time.

Power Costs

Electric power is undoubtedly very costly in this country as compared with coal or oil, but this is not the case in America and on the Continent, which is probably one reason why electric furnaces have been used more extensively than here. The power cost is to some extent offset by the greater thermal efficiency of the arc furnace as compared with the open-hearth. The B.t.u. consumed per ton of steel is only about a quarter of that for the open-hearth, but this does not bring fuel costs to the level of open-hearth, even with cold-metal charges. However, about 70-80% of the electric power required is used in melting-down the charge, and it would seem that considerable advantage could be obtained if liquid metal could be taken from a blast furnace or other pre-melting furnace. Unfortunately, all the expected advantages in economy of hot metal charges have not yet been obtained, even in America where considerable work on this process has been done[2]. On the other hand, certain developments have considerable promise—in Sweden, for example, charges with up to 70% of hot metal, as compared with the usual 30-40%, are being made, resulting in considerable economy[4].

Conclusions

To sum up therefore:—

(1) The electric furnace already produces steel of equal, and probably better, general quality than the open-hearth.

(2) The overall economics of the process already compare favourably with the open-hearth, and future developments will probably give it a significant lead in this respect. Present users of hot-metal charged open-hearth furnaces will have to consider seriously the use of large-capacity electric furnaces for refining, on all but the cheaper quality steels.

As a practical demonstration of the force of the argument for electric steel, at least two important steel producers have dismantled large open-hearth installations, both acid and basic, and replaced them by all-electric plants. This movement will undoubtedly spread widely in the immediate coming years.

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The Tensile Properties of Irradiated Uranium

By D. SHAW, B.Sc., A.I.M.
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AMERICAN results [1, 2] have shown that irradiation of uranium tensile test pieces causes some increase in the tensile strength but also results in serious embrittlement. The test pieces in that investigation were machined from unirradiated rod and were irradiated in containers, heat transfer being effected either by contact with close-fitting aluminium shapes or by immersion in Na-K alloy. In the current investigation, Hounsfield No. 14 test pieces (single-shoulder, with a gauge length 1 in. long and 0.252 in. diameter) were machined from full-section uranium bars, irradiated to different levels in a Calder Hall reactor. The remotely controlled lathe which was used has been described elsewhere [3].

The tensile tests were carried out at room temperature on a Hounsfield Tensometer, the strain measuring equipment of which was modified to give increased sensitivity. This was effected by measuring to a high degree of accuracy the number of revolutions (or part revolutions) of the spindle which drove the cross-head of the testing apparatus through a gear system. Thus the recorded extension consisted not only of the extension of the specimen but also of the deflection of the beam and of elastic strains in other components of the Tensometer.

TABLE I

TENSILE TEST RESULTS (AS-IRRADIATED TEST-PIECES)

Identity	UTS tons/in.²	Burn-Up MWd/te	Estimated Centre metal temp. °C.
1a	31.6	210	374 (±20)
1b	30.1	210	374
2a	28.8	270	374
2b	25.9	270	374
3a	28.5	380	269
3b	31.6	380	269
4a	30.0	410	436
4b	28.6	410	436
5	30.0	500	272
6a	25.0*	650	437
6b	30.9	650	437
7	20.0*	750	376
8	31.2	770	467
9a	28.8	850	452
9b	34.7	850	452

* These test pieces showed casting defects in the cross-section after fracture.

A typical load-extension plot is shown in Fig. 1. It will be noted that after the initial slackness in the grips has been taken up, the plot is a straight line to the point of fracture. Thus no plastic deformation has taken place and the value for the percentage elongation is consequently negligible (i.e. less than 0.2%). Tests were carried out on specimens covering a range of irradiation levels and temperatures (Table I); the constancy of the U.T.S. values is noteworthy. These lie mainly between 28 and 32 ton/sq. in. and are some 5 ton/sq. in. lower than that for unirradiated, beta-quenched, alpha-annealed uranium. It is clear, then, that irradiation up to about 1,000 MWd/te burn-up does not cause a progressive deterioration in strength. Furthermore, the strength and ductility after irradiation are independent of the irradiation temperature, in the range 269 to 467°C. Embrittlement occurs at an early stage, the ductility being negligible even after a burn-up of 200 MWd/te.

TABLE II

TENSILE TEST RESULTS FOR TEST PIECES ANNEALED AFTER IRRADIATION

Identity	Irradiation temp. °C.	Burn-up MWd/te	Annealing temp. °C.	Time of anneal h.	Y.P. tons/in.²	UTS tons/in.²	Elongation %
1	376	750	630	340	32.2	37.0	0.2
2	467	750	630	720	29.0	36.0	0.5

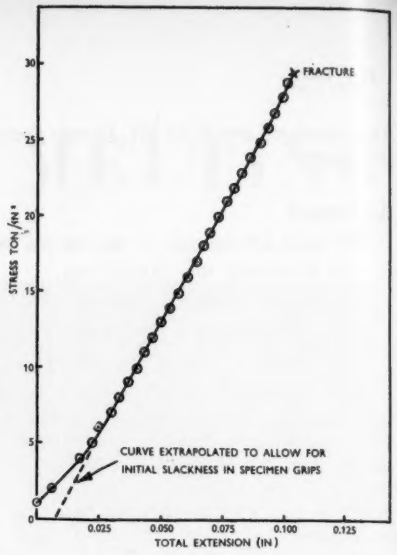

Fig. 1. — Typical stress extension plot for irradiated test piece.

Attempts were made to restore some ductility to the material by a prolonged anneal at a temperature high in the alpha range.

TABLE III

TENSILE TEST RESULTS FOR THERMALLY CYCLED TEST PIECES

Identity	Density change %	Cycling temp. °C.		No. of Cycles	UTS tons/in.²
		Upper	Lower		
TC 1	−2.18	640	270	15	14.9
TC 2	−0.43	624	255	19	27.9
TC 3	−0.91	585	229	23	16.6
TC 4	−0.34	585	229	22	23.5
TC 6	−0.49	636	245	21	22.0
TC 7	−0.81	645	257	20	16.3
TC 8	—	Not Cycled		—	29.3

Two test-pieces from bars irradiated to a burn-up of about 750 MWd/te were annealed at 630°C for 340 and 720 hours respectively. The results are quoted in Table II.

It will be seen that ductilities of 0.2 and 0.5% were obtained. These should be compared with a value of about 7% before irradiation. The U.T.S. values were significantly higher than those for the unannealed test-pieces. This may be ascribed to the effect of plastic deformation in relieving the stresses at the tips of stress-raisers such as pre-existing cracks or surface irregularities. Embrittlement during irradiation is probably caused by the anchoring effect of fission product atoms on the dislocation lines. The slight improvement in ductility after a prolonged anneal is probably caused by some precipitation of the fission products, thereby releasing the dislocations.

As thermal cycling in the alpha phase, during or after irradiation, is known to cause crack formation in uranium, it was decided to subject some test-pieces, prepared from uranium irradiated to 1,000 MWd/te, to thermal cycling treatments so that the effect of such treatment on the tensile properties could be assessed. The treatments, density changes and tensile test results are quoted in Table III.

The U.T.S. values are lower than those for the " as-irradiated " test pieces and show a close correspondence with the measured density increases. Metallographic examination revealed the presence of intergranular cracks, which accounted for most of the density change.

It is clear, therefore, that the loss of strength that results from severe thermal cycling conditions, is mostly due to the formation of intergranular cracks.

ACKNOWLEDGMENT

The author would like to express his gratitude to his colleagues C. McGuire and P. Hindmarch, who carried out much of the laboratory work for this investigation.

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IAEA's New Laboratory

By HENRY SELIGMAN

THE International Atomic Energy Agency (IAEA) was conceived in 1953, the main purpose being, as laid down in the Statute, "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world." It took a further four years before the Agency was eventually founded in October, 1957, and it was not until 1958 that this organization started to operate on a modest basis.

The functions of the Agency are fairly wide. Amongst the more important ones are the training of scientists in atomic energy—mainly the ones from the lesser developed countries, to give technical assistance in the form of experts and equipment to those areas, to hand out research contracts in order to foster the Agency's own programmes as well as filling important gaps, which may be of international significance, to recommend sites for reactors or even reactor designs, to evaluate the risk of reactors, to occupy itself with the legal aspects concerned with radiation risks from nuclear installations, nuclear-propelled ships as well as radioisotopes, to protect populations from radioactivity by recommending proper waste disposal methods and to promulgate the use of radioisotopes in medicine, agriculture, research and industry.

The initial idea of the Agency—to act as main supplier for fissionable material under international safeguard regulations for countries buying reactors — did not, and could not, materialize to the expected extent, as lesser developed countries have, for well-known reasons, so far not seen the necessity to purchase nuclear power reactors. For the research reactors purchased, bilateral supply arrangements are usually made. The Agency's role as a supplier of fissionable material, however, may be of greater importance in years to come.

It was obvious from the outset that, in order to fulfil functions such as standardization of radionuclides, analysis of reactor materials, checking of electronic instruments and so forth, a laboratory belonging to the IAEA would be necessary. After prolonged and heated arguments a decision was taken in September, 1958, to build a very modest laboratory to fulfil these functions. Even at that stage the laboratory would not have been built but for the generosity of the United States Government, who contributed $600,000 for the building and the equipment of such a laboratory. Since then, gifts of equipment have been received from the Governments of France and the Netherlands. Other large countries, which could well have afforded to make a special contribution to this first intriguing venture, have so far refrained from making gifts for this specific purpose.

The Agency's laboratory will be located on the site on which the Austrian reactor is being built and nearing its completion. This will be 20 miles south east of Vienna, at Seibersdorf. The Austrian facilities comprise a 5 MW swimming pool reactor (AMF) and laboratories for chemistry, physics, metallurgy, electronics and biology. The nearness to the Austrian establishment has the obvious advantage that many useful facilities are available and in view of the very close friendship which the IAEA has established with the Austrian authorities and the Oesterreichische Studiengesellschaft fuer Atomenergie, which is in charge of the activities, a very fruitful and unique collaboration can be foreseen.

Although the decision to build such a small laboratory, some 1700 m² in area, will perhaps look insignificant when compared to laboratory facilities in national or regional atomic energy establishments, it was a revolutionary step for an international organization to take, because, with the exception of one tiny morphium-checking laboratory, no truly world-wide international organization has any laboratory facility where Eastern and Western scientists work together.

The governing body of the IAEA may, therefore, be congratulated on the great foresight they have had to see the importance of such a laboratory for the future development of the Agency at such an early date. The laboratory is at present in the process of being built and will be in full operation by the spring of 1961. It will mainly occupy itself with:—

1. Standardization of radionuclides and the preparation of radioactive standards;
2. Calibration and adaptation of measuring equipment;
3. Control of nuclear materials and analysis in connection with the Agency's Health and Safety programme;
4. Measurements of environmental radioactivity and contamination of any products which member states would like to have analysed;
5. Measuring of tritium and the O^{16}, O^{18} ratio in water*;
6. Any service which member states may desire.

As a result of these activities, the building has had to include laboratories for chemistry, physical chemistry, radiochemistry, facilities for analyses like mass spectrometer, spectroscope, fluorimeter and polarimeter, a health physics laboratory, electronics laboratory and, in addition, the usual supporting facilities such as workshop, library, etc.

The secretariat of the Agency is fully aware that these modest facilities will not suffice—most likely not even satisfy demands during the first year—for all the functions which the Agency will be called upon to perform. The possibility has, therefore, been envisaged to hire additional laboratory space, if necessary, from the excellent facilities belonging to the Oesterreichische Studiengesellschaft. An expansion of the laboratory has also been planned for 1962, but it is as yet too early to say whether the necessary funds will be made available for such an expansion.

The recruitment of staff for the Agency's laboratory has just begun and will—in contrast to general rules applicable to international organizations—not be done on a purely geographical basis. The most suitable candidates, usually from the more developed countries, will be chosen so that practically all scientists working in this laboratory will have a good nuclear background. The only exception will be scientists who will receive special fellowships from the Agency to work with the laboratory staff in order to learn the procedures and techniques as applied in these facilities. It is envisaged as a start to have some 40 to 50 scientists working there during the first year of operations and to have at least 12 scientists as fellows.

It is obvious that such a laboratory cannot and should not serve purely functional work but in order to stay alive will obviously have to be used for research also. It would, therefore, not be surprising if some 20 to 30% of the over-all effort in this laboratory will be devoted to pure and applied research.

Research may not only be conducted in the fields of physics, chemistry and electronics but also in biology and agriculture, which could be achieved by using some of the Austrian facilities and which, through the kindness of the Austrian authorities, may be made available for this purpose. Next year will, therefore, be a critical twelve months for these operations. Should they be successful, this site may become the first truly international atomic energy site where East meets West and where scientists from all nations will work together not only to fulfil the present rather limited approved functions for the laboratory but perhaps equally to do research, teaching and learning on an international basis. Should this—a very likely concept—be verified, it may well be that within a few years a substantial number of scientists will be working at the outskirts of Vienna in this first great international venture and that the IAEA will have shown a new way in which international bodies can become truly effective—in a world where international co-operation is becoming more and more important. This will not only help the less developed countries but at the same time help to dispel mistrust between the great nations.

* This is for a special world-wide survey in order to measure, amongst other things, the water turn over rate which is of great significance for semi arid areas. The Agency's work would be mainly a corellating one.

Conference on Direct Conversion of Nuclear Energy

AMERICAN NUCLEAR SOCIETY

THE first conference held to discuss the methods of direct conversion of nuclear energy was arranged by the Pittsburgh section of the American Nuclear Society on March 19, 1960. The conference was attended by nearly 1,000 engineers and scientists from many branches of technology, both within the United States and abroad.

The first technical paper was given by Dr. C. E. Zener of the Westinghouse Electric Corporation, in which he discussed four methods of direct conversion of heat energy into electricity. In evaluating the all important overall efficiency of any power generation system, Dr. Zener showed that the analysis of a direct conversion cell was completely analogous with the evaluation of efficiency in a conventional heat engine.

The basis of most direct conversion schemes is to take advantage of the phenomenon of an interface electric field as occurs between a solid to solid interface in the thermoelectric conversion device or as between a solid to vacuum or gas interface as used in the thermionic heat engine. Another direct conversion system is the regenerative fuel cell which uses a chemical energy conversion process. The fourth system is the magnetohydrodynamic heat engine (MHD) in which an ionized gas is passed through a magnetic field and power is collected at two electrodes. This system is similar to a conventional heat-engine in that there is a hot working gaseous fluid.

Efficiency Problems

The problems associated with achieving reasonable efficiencies in these systems are the same, and by far the greatest source of lost power is the I^2R loss in the connecting leads and through the stray heat paths within the device. The improvements that must be looked for in order to insure the success of these devices must be in the field of improved thermodynamic design and in the development of materials which combine properties in a manner which so far has not been attained. Materials with permeabilities greater than iron and with poor properties of heat conduction are required.

Dr. J. R. Reitz of the Case Institute of Technology then described the process of thermionic conversion. The heat input is at the cathode, the working fluid is an electron gas and the output is taken from the anode. The device efficiency has been developed up to 30% with emitters operating at 30 W/cm². It is possible to use a cathode of uranium bearing material, for instance, uranium carbide which will operate in the region of 2,000°K and has good electron emission properties at this temperature; however, higher operating temperature in the range of 3,000-4,000°K are desirable. The anode provides the energy output and it is also the heat sink, therefore it may have to be cooled. Radiation cooling is adequate in most instances, the system thus lending itself to use as a generator for space vehicles.

Deleterious Effect

The deleterious effect of the space charge can be lessened either by placing the electrodes very close together (a separation in the order of 0.01 mm is required and this is a very difficult mechanical problem) or it can be achieved by filling the spaces with positive ions. This can be done by using cesium spacers with the electrodes about 1 mm apart; however, the compatibility of the electrode material with cesium and cesium vapour must be considered.

Theoretically, the space charge can also be neutralized either by a combination of magnetic and electric fields or by using a positive grid bias but these approaches have not yet been proved in practice.

Thermoelectric conversion was described by Dr. S. J. Angello of the Westinghouse Electric Corporation. The device efficiency of the converter is dependent on the operating temperature and on certain properties of the thermoelectric material. These properties are the Seebeck coefficient, the resistivity and the thermal conductivity. However, it is necessary for the material also to be capable of withstanding a high operating temperature and radiation damage, and to combine high electrical conductivity with poor heat conductivity. Development work is being done to find a material with an optimum combination of these properties.

The losses through lead resistance, stray heat paths, and from radiation at the higher temperatures all require consideration. The whole temperature range can be utilized by having each couple comprising several junctions of different parts of the temperature range. It seems that above 1200°C thermionic conversion will be more successful, but the development of a system using thermionic and thermoelectric converters in thermal series may prove successful. At present, it is envisaged that units of 100 W outputs powered by active isotopes will be developed for certain ocean and space applications.

Integration of thermoelectric material into a power reactor system may be either by conduction of the heat through a medium of liquid metal or water or by direct conduction by putting the thermoelectric material on to the fuel rods.

The possibility of developing outputs up to 10,000 MW by the magnetohydrodynamic converter was described by Dr. R. J. Rosa of Avco-Everett Research Laboratory. In this process, a hot gas or plasma is passed through an electric field and an electrical output is collected at two electrodes. The gas must be ionized to make it a conductor and as most gases do not ionize except at very high temperatures, it is necessary to seed the gas with an easily ionized element. Fortunately, the conductivity of a gas is almost as great if 1% of it is ionized as it is when 100% is ionized so seeding is most effective.

This device could replace the turbine in a power plant and carry with it the advantages of no internal moving parts or close clearances. In conjunction with nuclear power, it could be linked to the concept of a cavity reactor in which a seeded gas carries a gaseous fuel through a reaction vessel and a converter. With a gas pressure of 120 atm. and a reactor outlet temperature of 5400°K an output of 10,000 MW is estimated. However, the engineering and chemical handling and processing difficulties are of a major order.

Interesting Papers

Many other interesting papers were read which described the detailed studies and development projects which are currently being done in the U.S.A. Dr. A. M. Weinberg discussed the long term future of direct conversion methods and doubted whether any would become the most important conversion system. The problem is not the means of conversion, but the reactor. It is important to direct the long term future developments into reactor systems that will burn natural uranium and in this respect the direct conversion reactor may be a step in the opposite direction.

IODINE—

Its Removal From Gas Streams

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In assessing the safety of nuclear installations, the possible accidental discharge of iodine figures prominently. There is thus an increasing tendency for iodine removal systems to be specified in circuits discharging to atmosphere.

IODINE may be released to atmosphere as a result of the normal operation of homogeneous reactors, fuel processing, and the malfunctioning of heterogeneous reactors, or reactor loops. Being a condensable vapour its removal presents a difficult problem.

It is relevant to compare the activities released during the Windscale incident of October, 1957. Although the stack filters were not as efficient as they might have been,[1] they played an important rôle in preventing large quantities of radioactive particulate matter from reaching the atmosphere. An estimate of the magnitude of the release presented by Dunster[2] is shown in Table 1.

TABLE 1. Estimate of Activity Release During Windscale Incident

Iodine—131	20,000 curies
Caesium—137	600 curies
Strontium—89	80 curies
Strontium—90	9 curies

But apart from the health hazards, as iodine-135 is a precursor of xenon-135, one of the most serious of the thermal reactor poisons, its removal from systems employing liquid fuels may become important.

Iodine has a melting point of 114°C and a boiling point of 184°C. Its vapour pressure is appreciable (1.03 mm Hg) at 40°C. Air saturated with iodine at this temperature would contain 1.2% I_2 or 13.5 g/m^3. As the maximum concentrations of iodine likely to be found in a contaminated reactor circuit or in a fuel-dissolving vessel are factors of 10^3-10^6 down on this, one would expect all the iodine to be present as vapour. This is only true if the gas contains no "condensation nuclei." In its widest sense this term covers any aerosol on which a vapour may condense or adsorb; more specifically, it is reserved for charged particles. The sizes of such nuclei[3] are usually less than 0.1 μ and they are therefore difficult to filter from gas streams. Iodine, even when present in concentrations as low as 0.1 μg/m^3, appears to adsorb on condensation nuclei and on lead fume[4] at room temperature. Concrete dust also adsorbs iodine at moderate temperatures, desorbing it again at elevated temperatures (>600°C)[5].

Gordieyeff[6] suggests that an aerosol cloud previously exposed to a high concentration of vapour will readily desorb the vapour on passing through a scrubber. This is unlikely to be true for aerosols exposed to low concentrations of vapour.

If a small quantity of iodine is liberated in a gas stream containing aerosols, some will remain as I_2 vapour and behave as such, and some will adsorb on the aerosol, and behave as particulate iodine. The size of the fraction which adsorbs on aerosols depends on the concentration of the aerosol, its nature and the length of time elapsing between the iodine release and its measurement or treatment. This is because the adsorption mechanism takes a finite time to occur. For example, in a fuel dissolving vessel both the aerosol concentration and the iodine residence time are likely to be small. When the iodine reaches a scrubber or a similar treatment system, most of it is likely to be present as I_2 vapour and as such would be removed. If, however, iodine is released from a burning fuel rod in a circulating gas circuit with the treatment system on a bleed-off from the main circuit (thus allowing some time to elapse between release and treatment) then it is most likely that the bulk of the iodine will be adsorbed on uranium fume and a caustic scrubber on its own, for example, would not be very efficient.

The choice of a suitable treatment system must be made bearing in mind the possible physical forms in which the iodine may be present.

Iodine Removal Methods

Substances which will remove iodine from gas streams can be divided into two main groups—liquids and solids. The former are further divided into reversible and irreversible absorbants, and the latter into physical (or Van der Waal) and chemical adsorbers in Table 2.

TABLE 2

Liquid agents		Solid agents	
Reversible	Irreversible	Physical adsorbers	Chemical absorbers
Water Organic amines 30% Tri-butyl phosphate/ Kerosene Alkali iodide solution Alkali sulphite solution	Alkali hydroxide solution Alkali carbonate solution Alkali thiosulphate solution Mercury Silver sulphate solution	Active carbon Silica gel Molecular sieves Graphite	Aluminium Alumina Magnesium Magnesia Magnesium carbonate Calcium Copper Copper oxide Mercury oxide Potassium iodide Silver Silver nitrate Silver iodide Zinc Zinc oxide and many others

Liquid Absorbers

Scrubbing with water can give high decontamination factors (D.F. is defined as inlet concentration divided by exit concentration) against iodine vapour providing the

concentration of iodine in the water is kept to a low value by frequent bleed-off and make-up of water; 30% TBP/OK is reported[7] to have given D.F.s of 10^4-10^5 against iodine in dissolver off-gases. Caustic soda solution is used widely with satisfactory results in packed towers[8, 9] and has been used in a venturi scrubber[10]. Taylor[11] has determined the overall gas coefficients for removing iodine vapour from air with sodium thiosulphate, iodide, hydroxide, and tetrathionate, and with water. Silver sulphate solution forms an efficient scrubbing solution for iodine vapour[12] and absorption into sodium carbonate solution is also effective[13].

Liquid absorbers are usually employed in packed towers and these are best suited to steady, continuous operation. Sudden surges of gas are not easily accommodated, nor are small particles efficiently removed. The possible reaction of the carrier gas with the solution must be borne in mind. Thus, if caustic soda is employed against a gas containing high concentrations of carbon dioxide, the liquor will be converted to sodium carbonate. Further conversion to bicarbonate will follow until an equilibrium mixture of the two salts is obtained, the proportions depending on the CO_2 concentration.

Packed towers should not be employed against large quantities of hot gases or excessive evaporation will occur. Entrainment of contaminated droplets must be avoided by careful design. Finally, it should be realized that the solution will become radioactive and there may then be an active liquid effluent problem.

Solid Chemical Absorbers

Iodine reacts at room temperature with magnesium, calcium, aluminium, zinc, tin, nickel and iron[14], and with lead and bismuth at 200°C[5]. Oxides of magnesium and aluminium[5, 14] and of lead and bismuth[5] also absorb iodine vapour. Copper reacts with iodine vapour at room temperature and at 300°C[5] but the surface must be clean. Copper oxide has only moderate efficiencies[15] against iodine up to 200°C and above this temperature, desorption takes place. One would therefore expect that if copper is used for long periods in air at $\geq$ 240°C, the efficiency would fall off due to the formation of the oxide.

Silver, silver nitrate and silver iodide are frequently employed on dissolver off-gases. Alundum pellets, Raschig rings or Berl saddles are immersed in 18-20 molal silver nitrate solution, drained and baked at 220°F for 4 hours[16]. The unit is operated at around 350°F and the collection efficiency is said to be 99.99% (D.F. $\simeq 10^4$), initially, decreasing over the period of a year when regeneration becomes necessary. The average efficiency is about 99.5%. Silver-plated wire mesh is less efficient than silvered alundum, although its efficiency increases with packing density[17]. The alundum has a much higher iodine adsorption capacity than the mesh, virtually 100% saturation being achievable without significant loss of efficiency, compared with 2% for mesh. Thermal cycling of silvered mesh between 30°C and 400°C releases no appreciable iodine. One disadvantage of units based on silver and silver salts is that they must be maintained at around 200°C continuously and this may require large quantities of heat if the gas flows are large.

Solid Physical Adsorbers

Activated carbon is well known for its ability to remove traces of materials from gases and liquids. The iodine-adsorption test is a standard method of testing the ability of a carbon to remove odours and flavours from gases and liquids. The carbon is immersed in a standard iodine-containing solution and the proportion of iodine taken up is measured[18].

Activated carbon has been tested against trace quantities of radioactive iodine by a number of workers. Much of the work has been carried out under conditions which suggest that relatively few condensation nuclei were present, and the results therefore apply mainly to iodine vapour. Few workers specify precisely the type of carbon employed in their experiments. This is unfortunate because the activity of carbon varies, depending on the source of the raw material and the method of manufacture. Finnegan[19] obtained D.F.s of 10^5 in removing iodine from helium and Adams[20] reports D.F.s of 2,000. Although the adsorption does not involve a chemical reaction, the iodine is held strongly at 200°C and higher. Increasing the flow rate by a factor of 20 and increasing the temperature to 80°C did not desorb iodine in Finnegan's experiments. The presence of moisture does not appear to adversely affect the adsorption efficiency and up to 5% water in the carbon has no effect[20]. Ramat[21] subjected active carbon to thermal and humidity cycles for long periods without diminishing its adsorptive ability.

The bulk of the iodine is trapped within the first half inch of bed depth[9, 19, 20] and "creep" of the iodine towards the bed outlet does not occur. The efficiency of the bed for iodine diminishes rapidly towards the bed outlet. Thus, to decrease the I_2 concentration by a factor of 10 required only 0.17 in. at the bed entrance but almost 19 in. at the outlet[20]. This suggests that some iodine was present adsorbed on small particles, and emphasizes the difficulty of dealing with iodine in that form.

Graphite adsorbs iodine vapour at 200°C[5] and can be heated to 350°C without desorption occurring. Up to 40% desorption occurs when it is heated in air to 450°C but even at 750°C desorption is incomplete.

Molecular sieves are synthetic zeolites with a definite crystal structure containing large numbers of minute pores and passages which are uniform in size. On a 22 in. deep column at room temperature D.F.s of approximately 10^5 have been obtained[22] but it was necessary to dry the gas initially as, unlike active carbon, iodine can be displaced from molecular sieves by water vapour. The distribution of iodine along the column was completely different from that on activated carbon, being more evenly spread through the depth of the bed.

There is a problem involved in using solid adsorbents which does not arise with liquid absorbents; this is fission product heating. Usually the volume of liquid absorbent employed is sufficiently great to accommodate large quantities of heat without causing boiling, cooling is relatively simple and, at worst, the solution temperature cannot exceed boiling point. With a solid adsorbent, however, a small mass of material is involved, cooling is not easy, and very high temperatures may be reached causing desorption or even fires. This may be particularly serious in the case of carbon, where it was seen above that most of the iodine deposits in the first inch or so of bed depth. It has been estimated[23] that the decay heat released in a silver unit attached to a homogeneous reactor may amount to as much as 21,000 B.t.u./h initially.

REMOVAL FROM REACTOR LOOP

The factors which must be taken into account when choosing an iodine removal system are best demonstrated by considering a specific problem. Assume that an iodine removal unit has to be provided for a new in-pile testing rig. A new type of fuel element is to be tested in a high flux reactor at high temperatures and pressures. The coolant is, let us say, CO_2. Fig. 1 is a diagrammatic sketch

of the hypothetical rig. The usual instrumentation is provided—pressure, temperature, radioactivity monitors, etc., and the loop is blown down to atmospheric pressure in order to change fuel elements.

Fault Conditions

First of all it is necessary to consider briefly in what circumstances a circuit is likely to be contaminated.

(a) Although two coolant circulators are provided, the consequences of coolant failure must be considered. The fuel elements would immediately rise in temperature and although some cooling would be obtained by natural convection this might not be adequate to prevent overheating of the element and possible rupture, or fuel melt-down. Iodine and the rare gases would be liberated into the circuit.

(b) Failure of the fuel element due to local overheating or a weld failure is possible. Again the circuit would be contaminated although not as badly.

(c) The heat exchanger coolant supply may fail. This again would cause overheating and possible can rupture or melt-down.

The circuit activity monitors would record the accidents and the reactor could be tripped. In case (b), if the failure is not a bad one, it might be possible to continue running the blowers to cool the elements without increasing the circuit contamination, if not then the circuit would be blown down. In cases (a) and (c), blow-down after reactor shut-down is the only possible course of action, although it need not necessarily be carried out immediately. It is evident therefore that the iodine unit must be installed on the blow-down line, and not in the main gas circuit, as the use of the blowers either cannot be guaranteed or may not be desirable.

Cooling of Blow-down Gas

Having decided the position of the unit on the rig, the advantages and disadvantages of each of the possible treatment systems must be weighed. This problem is inextricably involved with another—whether or not the blow-down gas is to be cooled before treatment. Under normal blow-down conditions the discharge gas temperature may be around 150-200°C, but in adverse circumstances it could reach 600°C. None of the solid agents could operate efficiently at this temperature. A simple calculation shows that in a scrubber containing 50 gal of 10% sodium carbonate, the liquor would be heated almost to boiling point. Larger quantities of liquor could be used but the unit then becomes very bulky for such a small duty. Apart from the overall heating effect, when the hot gas reaches the bottom of the packed tower there is a danger of flooding due to the instantaneous production of steam.

It would, therefore, be advisable to employ some type of heat exchanger to cool the gas. The type of heat exchanger chosen must be completely reliable, compact and ready for use at a few minutes notice.

Heat exchangers based on counter current or cross flow of the gas over water-cooled tubes could be quite compact, but ensuring the water supply at all times might be difficult. Almost every scheme is subject to the possibility of failure of pumps or else is bulky and expensive (e.g. a water tower).

A more suitable type of heat exchanger for this application is a heat sink. This is simply a mass of material such as granite chips or steel ball bearings, through which the gas passes and to which it transfers heat. It has a number of important advantages over other exchangers, requiring no moving fluid other than the gas, no pumps or valves. It is ready for use at all times, requires no maintenance and is cheap to make and install. Moreover, it occupies very little space. For this particular application about one cubic foot of ½-in. granite chips would cool all the gas from 600°C to less than 100°C. After the blow-down is completed the heat sink cools by natural convection. One disadvantage of the heat sink is that some particulate fission products may deposit on the granite chips causing the bed to become active. Shielding would therefore have to be provided.

Iodine Removal Methods

In order to specify the performance which would be required from the iodine removal equipment, let us assume

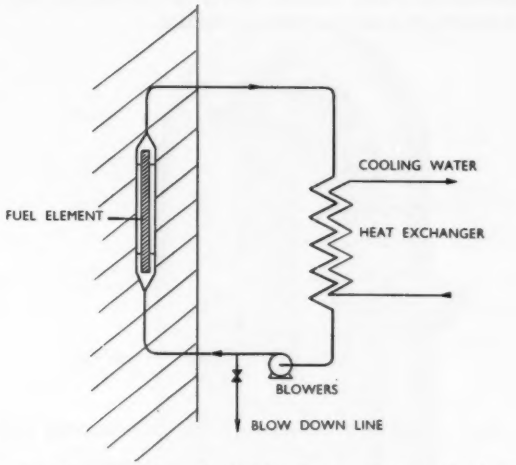

Fig. 1.—Diagram of hypothetical in-pile rig. For specification see table "A".

TABLE A

In-pile Fuel Element Testing Rig Specification

Construction materials	Stainless steel
Circuit pressure	300 p.s.i.
Max. gas temperature	450°C
Min. gas temperature	200°C
Heat exchanger	Water-cooled tubes
Mass of CO_2	12 lb
No. of circulators	2
Blow down time	5 minutes

that 500 c of iodine-131 are released in the loop. This would represent a very serious incident and large amounts of radioactivity from other fission products (rare gases and solid particles) might also be present. On a semi-remote U.S. site the allowable iodine-131 release is 0.1-0.5 c/day[7]. However, in the event of an isolated incident, it is likely that the permissible figure is higher by a factor of 10. Using a figure of 5 c for the purposes of this example, the equipment installed must be capable of giving a decontamination factor of 100.

As the gas is being discharged from a high-pressure loop, the choice of iodine equipment is not limited by pressure drop considerations. Without performing any fluid flow calculations on the system it is not possible to say what the absolute pressure is likely to be in the treatment plant at a given time. This pressure depends, among other factors, on the pressure drop across the plant. It is likely, however, to be of the order of 10-20 p.s.i.g. in the equipment, and this must be borne in mind. Space is at a premium around a research reactor and the equipment should be as compact as possible.

Liquid Absorbers. One general criticism of liquid absorption systems is that, like heat exchangers based on fluid coolants, it is difficult to ensure their availability at a

few minutes notice. It would be possible to run the scrubber continuously but an incident may occur just as the pump has broken down. Accidents have an unhappy knack of occurring at such times! One should then provide for duplicate pumps. A packed scrubber based on caustic soda or sodium carbonate would be approximately 8 in. diameter by 8 ft high in order to obtain a D.F. on iodine vapour of 100. In addition, two pumps and a 50 gal tank would be required. The system might need to operate under a pressure of 10-20 p.s.i.g. The advantage of a system based on caustic soda is that all the CO_2 could be absorbed and only the rare gases would emerge from the top of the scrubber. These could be stored if necessary so that there need be no discharge at all to atmosphere. The scrubber and its tank would be radioactive after an incident and would have to be shielded.

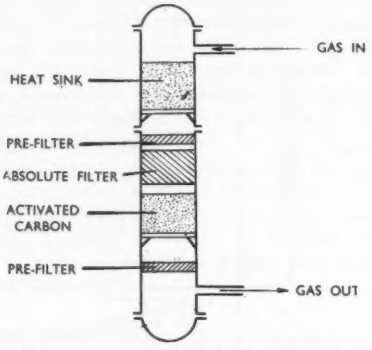

Fig. 2.—Diagram of a cheap and simple iodine absorber unit.

Solid Agents. A silver unit such as described previously suffers from a similar disadvantage to that of the scrubbers; as it needs to be operated at around 200°C it would have to be maintained at this temperature at all times. Besides being costly in electrical heating, breakdown and maintenance would have to be covered by providing two units. There is insufficient data on copper and other metals and it seems unlikely that they can be relied upon to give a D.F. of 100. Activated carbon is known[19, 20] to give D.F.s greater than 100 against iodine vapour at temperatures up to at least 200°C. It has the advantage that there are no heaters, no moving parts and it is ready for instantaneous use. It is, moreover, compact, as for this problem the bed would be 1 ft diameter by 1 ft deep.

Preferred System

The cheapest, simplest, safest and smallest arrangement is that shown in Fig. 2 consisting of a heat sink and an activated carbon bed. The advantage of being able to absorb all the CO_2 in a caustic soda scrubber is outweighed by other considerations. The heat sink is followed by a prefilter which removes particles down to 5 μ with 99% efficiency. This filter would remove the bulk of the particulate fission products and any carry over of dust from the heat sink, thus protecting the "absolute" type filter through which the gas passes next. This filter is included in order to remove the very small particles (down to 0.1 μ) on which some of the iodine would adsorb, and the remaining particulate fission products. The "absolute" filter is followed by the activated carbon bed. Down flow of the gas on to the top of the bed is preferred to both horizontal- and up-flow. The danger of loss of efficiency due to settling of carbon in a horizontal-flow bed and partial fluidization of an up-flow bed is thus avoided. Finally, another prefilter is arranged at the bottom of the unit to capture any carbon dust with attached iodine. All the filters should be fireproofed, although fission product heating presents little problem in this case. These individual items would be accommodated in a cylindrical steel shell 6 ft long by 1 ft internal diameter, designed to withstand the appropriate calculated internal pressure.

Conclusions

The hypothetical loop was discussed above in some detail in order to illustrate how essential it is to consider each problem on its merits. There is no single iodine removal unit which can be used for all problems. The unit preferred for the loop would not be the best for, say, the clean-up of ventilation air, where pressure drop is an important consideration.

As nuclear plant installations become more widespread they will inevitably be situated nearer large centres of population. Nuclear-powered ships, for example, would use the world's major ports. While attention is being given towards making installations intrinsically safer, a great deal of thought and money all over the world is being devoted to external safety devices. The report of the committee on the safety of nuclear-powered merchant ships[24] discusses fully possible accidents and their consequences, and suggests tentatively that an iodine scrubbing unit might be provided outside the containment vessel. It is not unreasonable to suppose that the time will come when all nuclear installations will include some sort of iodine removal unit as an integral part of the plant.

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HWCTR

The Savannah River Components Test Reactor*

KNOWLEDGE of the behaviour of fuel elements under actual working conditions is perhaps the most vitally important piece of information required in conducting feasibility studies on any type of reactor. In order to assist with their studies of the feasibility and economics of natural uranium heavy water power reactors the HWCTR (heavy water component test reactor) is being constructed at the Savannah River Laboratories of E. I. du Pont de Nemours and Co. The reactor will be unclassified and access will be permitted to authorized U.S. and foreign representatives. Criticality is scheduled for early 1961.

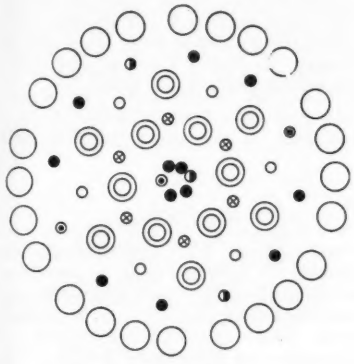


Fig. 1. (Left)—Plan of core lattice.

DRIVER FUEL ASSEMBLY (ENRICHED URANIUM)
TEST FUEL ASSEMBLY (NATURAL URANIUM)
BLACK FULL ROD
BLACK HALF ROD
GREY FULL ROD
SAFETY ROD
INSTRUMENT POSITION

The HWCTR is a 50 MW unit moderated with heavy water operating at a coolant temperature of 240°C (464°F) but pressurized to 1,000 p.s.i. with helium to prevent bulk boiling. The maximum operating pressure is 1,500 p.s.i. Cooling is by means of heavy water—light water heat exchangers, the steam generated being released to atmosphere, with the exception of a small percentage for auxiliary turbines driving feedwater pumps.

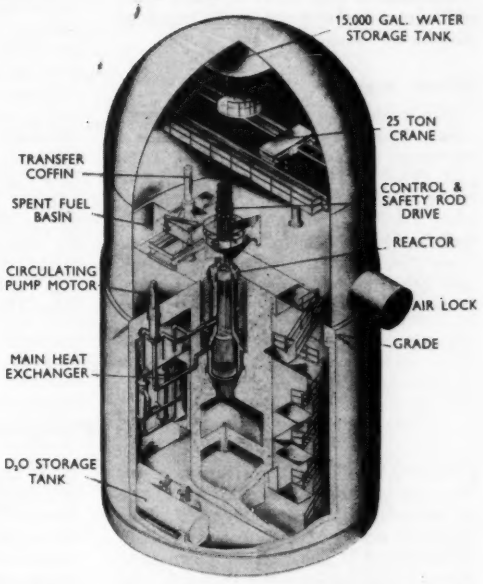


Fig. 2. (Right)—Cutaway view showing reactor arrangement.

Core

The lattice design, as will be seen from Fig. 1, is unusual. The "driver" elements, i.e., those providing the actual operating power, are arranged on the outside of the core, the centre of the core being occupied by the elements under test. The overall diameter of the core inside the thermal shield, i.e., including reflector, is 6 ft 4 in., the active length some 10 ft.

The driver elements, 24 in number, are located on a circle of 40 in. diameter. Each element is 2.27 in. diameter and is made of zirconium-oralloy and contains 108 grammes of U^{235} per foot. Each element is housed in a Zircaloy tube with an i.d. of 2.9 in. In the centre of each element is a target of stainless steel containing boron as a burnable poison.

The test elements for the first reactor charge will be natural uranium in tubular form, 2.06 in. o.d. and 1.467 in. i.d., each containing 110 lb of natural uranium metal. The test elements are located in a triangular lattice of 7 in. pitch; at the centre of each triangle is a thimble for flux measuring instruments.

Control

There are in all 24 control and safety rods, black, black half rods (i.e., half

Table 1. General Parameters of HWCTR

Thermal power	50 MW
Operating pressure	1,000 p.s.i. (70.3 kg/cm²)
Maximum pressure	1,500 p.s.i. (105.5 kg/cm²)
Operating temperature (av.)	240°C (464°F)
Core	
Overall diameter (including reflector)	76 in. (1.93 m)
Driver element circle dia.	40 in. (1.016 m)
Fuel element dia.	2.27 in. (57.5 mm)
Housing tube i.d.	2.9 in. (73.5 mm)
No. of driver elements	24
No. of control rods Black	12
Black half rods	3
Grey	3
Safety (black)	6
Outside dia. of control rods	1.25 in. (31.7 mm)
Inside dia. of control rods	1 in. (25.4 mm)
Test element lattice	Triangular, 7 in. (17.8 cm) pitch
No. of test positions	12
Test fuel elements o.d.	2.06 in. (52.7 mm)
Test fuel elements i.d.	1.467 in. (37.2 mm)
Test fuel elements cladding	0.015 in. (0.38 mm)
Power per element	1.2 MW
Metal temperature (max.)	550°C (1,022°F)
Sheath temperature	285°C (545°F)
Heat flux (max)	420,000 B.t.u./ft², h (1,139,040 kcal/m², h)
Coolant	
Flow in each test element	300 gal/min
Total flow in reactor	9,600 gal/min
Temperature in test elements (av.)	225°C (437°F)
No. of steam generators	2
Heating surface	2×2,500 ft² (233 m²)

*Abstract of AEC Research and Development report DP–413 compiled by L. M. Arnett (E. I. du Pont de Nemours and Co.) from the following papers presented to the American Nuclear Society:

- "The Heavy Water Components Test Reactor (HWCTR)" by L. M. Arnett.
- "Neutron Economy in a Critical Mock-up of the HWCTR," by N. P. Baumann, W. E. Graves and G. F. O'Neill.
- "Flux Distributions in a Critical Mock-up of the HWCTR" by W. E. Graves and T. J. Hurley.
- "Calculations of Physics Parameters of the HWCTR," by J. W. Wade.
- "Power Excursions in the HWCTR," by D. Randall and D. S. St. John.

length) and grey. Grey rods are plain stainless steel; the black rods are stainless with 1.5 per cent boron. All are tubular with an o.d. of 1.25 in. and an i.d. of 1 in. The locations of the rods are shown in Fig. 1. Six control rods, four black, one half-black and one grey, are located at the centre of the core and 12 further rods, eight black, two grey, and two half-black, are arranged in a circle outside the test elements and inside the driver elements. The six safety rods, identical with black control rods, are arranged in a circle between the two groups of control rods.

The control rods move in guide tubes which extend almost the whole length of the reactor vessel.

Pressure Vessel

The main pressure vessel is approximately 29 ft high and is designed for a maximum operating pressure of 1,500 p.s.i. The thickness varies from 3.5 to 4.5 in. of carbon steel lined with stainless steel. The head, which is attached by 32 studs, carries the control rod mechanisms; when the head is removed the control rods are unlatched from their operating mechanisms which are then withdrawn into the head for safe stowage.

At about the mid-point of the length of the vessel there is a dividing plate which supports the upper end of the fuel element tubes.

Coolant

The circulating D_2O enters the vessel above the shield, passing down the fuel assemblies, and discharging at the bottom of the fuel housings. It then passes upwards through the moderator space and flows out near the top of the core below the shield. The pressure drop across the fuel is about 28 ft H_2O (approximately 12 p.s.i.). Flow and temperature is measured in individual fuel assemblies by pressure tappings and thermocouples in each assembly.

There are two main coolant loops each with a vertical centrifugal pump and heat exchanger. The normal circulation is 4,800 gal/min in each loop. Each of the D_2O/H_2O heat exchangers has about 2,500 sq ft of heat exchange surface consisting of $\frac{1}{2}$ in. tube in vertical loops; the secondary steam pressure may be varied up to 500 p.s.i. for power regulation. The steam will be discharged at a point 250 ft from the reactor building.

The moderator level in the reactor vessel is maintained at about 6 ft 6 in. above the inlet nozzle, the space above the nozzle being pressurized with helium.

The pD of the moderator will be held at about 10-11 to protect the carbon steel in the system, adjustment being made by regulating the flows through two parallel ion exchange beds. The oxygen content will be held to low values by the presence of excess deuterium in the helium blanket system.

Reactor Building

The reactor building is 70 ft diameter and 125 ft high of which about half is below ground level and built of prestressed concrete 18 in. thick and wrapped with $1\frac{3}{16}$ in. steel cables spaced at 1 ft intervals and stressed to 160,000 p.s.i. The upper portion is a steel dome anchored to a concrete shell designed to withstand an internal pressure of 24 p.s.i. (slightly greater than the equilibrium pressure which would result from flashing all the D_2O in the system at 285°C). The dome contains a storage tank holding 15,000 gallons of water which can be released through a sprinkler system for quenching any released steam.

Progress at Dresden

CRITICALITY at Dresden was achieved on October 15, 1959, and to judge from a paper by J. J. Poer (Commonwealth Edison) and V. D. Nixon (General Electric) at the American Power Conference in Chicago, the station is in the state known in shipping circles as "working-up."

Although fuel element manufacture has been described (*Nuclear Engineering*, June, 1959, p. 253) and various news items have appeared from time to time, no complete description of the station has yet appeared in these pages. It is, perhaps, appropriate to note that this is the largest all-nuclear plant in the U.S.A., having a net electrical output of 180MW from a single reactor of the dual-cycle boiling water type with a thermal output of 625.9MW. Located at Morris, Illinois, it has been designed and constructed by the General Electric Co., for the Commonwealth Edison Co., and the Nuclear Power Group Inc., which includes American Gas and Electric; Central Illinois Light; Commonwealth Edison; Illinois Power; Kansas City Power and Light; Pacific Gas and Electric; Union Electric Company of Missouri; and the Bechtel Corporation, which is acting as engineer-constructor. The complete contract is in the hands of General Electric, the contract price being $45m.

Construction began in March, 1957, and the sphere (Chicago Bridge and Iron Co.) was completed in April, 1958. The pressure vessel (New York Shipbuilding Corporation) arrived in March, 1959, after a 25-day voyage down the Atlantic seaboard, through the gulf of Mexico and up the Mississippi and Illinois Rivers. The completion of the station within two weeks of a date scheduled 3½ years previously (and well ahead of contract) is a tribute to the meticulous thoroughness of the planning.

Testing

The same painstaking care was applied to the preparation of the plant, and preoperation testing. All piping and equipment was water-flushed, blown with steam, and chemically cleaned until the desired degree of cleanliness had been established by inspection and analysis. Hot citric acid was normally used for cleaning, and it is interesting to note that one flushing required 200,000 gallons.

Yet another example of "nothing-but-the-best" concerns the fuel elements. Although, as previously recorded, the cladding tests were stringent, a new testing procedure (eddy current) revealed minute imperfections in the Zircaloy, not previously observable, at a time when 70% had already been dispatched. Nevertheless, the entire shipment was returned to San Jose for re-testing.

During the final construction stages, a testing group, composed of G.E., Commonwealth, and Bechtel staff, was formed to carry out pre-operational testing. In addition to the tests undergone during construction, no fewer than 55 system tests were scheduled, ranging from the reactor unloading system to the d.c. auxiliary supply and the "domestic" water system. Fuel loading began on October 13, 1959. A hitch occurred due to sheared control rod pins; this was rectified and loading continued in planned steps, and after a further hitch in December has progressed steadily. At the beginning of April 450 elements had been loaded and the pressure vessel head bolted down.

At various stages the core has been taken critical and measurements of core parameters have been very close to the predicted figures. It has been confirmed that the temperature coefficient becomes negative at around 120° C, and the reactor is now steaming. Half-power—the maximum permitted under the present licence—should be reached by the beginning of May and although hand-over date is not until December 8. provided permission is granted full-power operation can be expected by July.

Staff Training

Training of staff commenced back in 1957 and has varied, according to the grading of the persons concerned, from a basic course taken by almost everybody, to a 12-month course devoted to reactor technology alone in the case of nuclear and instrument engineers. Other courses were taken at G.E., at Oak Ridge, Hanford, Argonne, Tracerlab Inc., and Robert A. Taft Sanitary Engineering Centre. Eight members of the staff qualified for their AEC operating licences at Vallecitos. In all, some 46 man-years have been spent in training.

SPERT-II

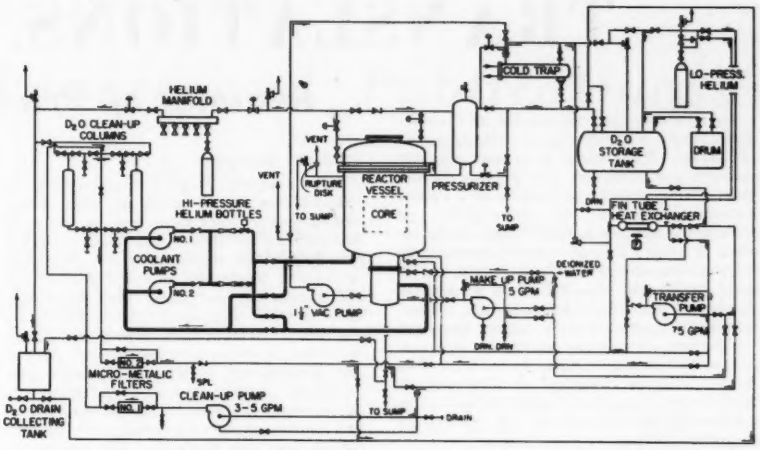


Fig. 1.—Simplified flow diagram of the reactor coolant and pressurizer circuits.

THE third in chronological order (if not in nomenclature) of the Special Power Excursion Reactor Tests facilities—SPERT-II became critical for the first time on March 11. This series of experimental reactors has been devised to evaluate the safety characteristics of liquid moderated reactors and their general behaviour *in extremis*. SPERT-I which is an open tank type and was completed in 1955 has provided valuable data at atmospheric pressures and near ambient temperature on the kinetic response of pool type reactors to step and ramp changes in reactivity. SPERT-III, completed in 1958, extended the scope of these experiments to cover pressurized systems and was designed to operate at 2,500 p.s.i. and 670°F. SPERT-II operating at moderate temperatures and pressures will be used to obtain information on the influence of prompt neutron lifetime on reactor transients and is designed to accommodate different moderators and reflectors—particularly light and heavy water. It has been constructed near the other two reactors at the NRTS, Idaho Falls.

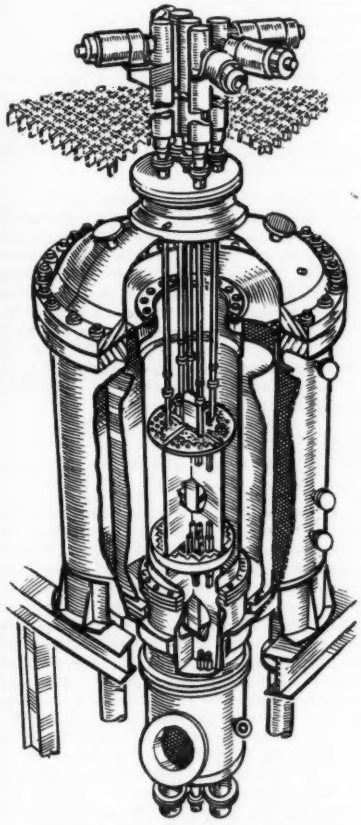


Fig. 2.—Cut-away view of the reactor showing the division of the core into quadrants and a typical poison shield in position.

General Arrangement

The general construction of the reactor is shown in Fig. 2. The pressure vessel and hemispherical head 10 ft i.d. x 24 ft 6 in. overall height is of 1.5-in. A-212 Grade B carbon steel clad with 0.1-in. type 304 L stainless steel. Design pressure is 0-375 p.s.i.g. and design temperature is 400°F. The top can be removed complete or, for access to the core only, a 42 in. diameter closure can be opened. The bottom end carries a 42 in. diameter manifold which includes immersion heaters rated at 200 kW, and a 24 in. coolant nozzle. Surrounding the manifold are four additional nozzles.

The core is supported from the bottom of the vessel and is made up of a maximum of 96 fuel boxes. Fig. 3 shows a more typical arrangement of 28. The boxes are 2.990 in. by 2.960 in. by 37.625 in. and are arranged to contain either 12 or 24 flat fuel plates made up of 0.020-in. 93.5% U-Al alloy sandwiched between 0.020-in. Al plates, each plate 25 in. long containing 7g U^{235}. The core is divided into quadrants by a water-filled aluminium cruciform in which the Al-Cd-Al transient rod moves. Control is effected by eight fuel/absorber assemblies carried in pairs on four yokes each with separate but similar drives. The assemblies are similar to the fuel boxes at their lower ends but are surmounted by poison sections 45 in. long made by spraying 0.020 in. of cadmium on to a stainless steel box and covering, by spraying, with 0.040 in. of stainless steel.

The rod drives comprise essentially a combination motor and pneumatic system, a positive differential pressure being maintained on the undersides of the piston to drive the rod up against the screw. For scram operation the underside pressure is vented to atmosphere. Maximum withdrawal rates of the control and transient rods are 20 in./min, total travel being 36 in.

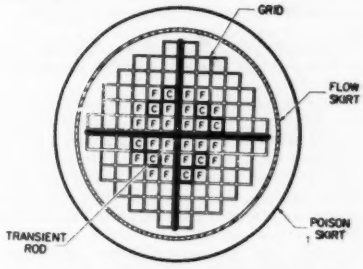


Fig. 3.—Typical core; F denotes fuel element, C denotes control assembly.

Surrounding the core is a flow shell also mounted from below which directs the coolant around the core. This coolant can then be mixed with the reflector or isolated in a separate circuit. The thickness of reflector is defined by a poison shell which can be of varying diameter and decouples the reacting volume from the rest of the pressure vessel volume.

The coolant circuit is designed for operation with either light or heavy water and crossover connections permit either upwards or downwards flow. Two primary pumps each of 10,000 gal/min capacity at 175 ft head are driven by electric motors through fluid couplings permitting adjustment down to 2,000 gal/min and to 200 gal/min, by operation of a flow control valve. The system is pressurized with helium which also serves as blow-down and purge gas.

The reactor is housed in a 90-ft by 60-ft building with the control room located about half-a-mile away.

TRANSLATIONS

Résumés of Principal Articles

Suede (page 199)

Un programme de construction de centrales nucléaires est à l'étude depuis plusieurs années en Suède. On s'attend à ce que plusieurs centrales soit démarrées dans environ dix-huit mois. Trois tendances se manifestent à l'heure actuelle:—poursuivre la construction de réacteurs à uranium naturel et eau lourde (ce type a reçu l'appui de l'administration jusqu'ici)—construire un réacteur à eau bouillante de 50 MW. Il s'agit d'une proposition d'un consortium d'entreprises privées spécialisées dans la production de courant électrique —construire une centrale souterraine comportant un réacteur gaz-graphite. La roche en place servirait d'écran biologique et d'enceinte de confinement. Ce projet a l'appui de l'organisme gouvernemental chargé de la production d'électricité.

L'expérience de l'industrie suédoise dans le domaine nucléaire continue à progresser. La production d'uranium à partir de minerais à faible teneur se poursuit activement. La tendance à utiliser l'uranium naturel comme combustible nucléaire est très marquée.

Finlande (page 205)

Les possibilités de production d'énergie par les méthodes conventionnelles seront pratiquement épuisées dans un proche avenir en Finlande. Il y a donc pas mal de chances pour que plusieurs centrales nucléaires soit construites jusqu'en 1970. Un programme d'entraînement de personnel est en train de démarrer. Il précédera la phase de construction des centrales. La situation actuelle de la production d'énergie en Finlande est analysée. L'état critique dans lequel elle se trouve présentement est décrit.

Applications dans le Domaine Nucléaire des Aciers Produits dans les Fours Electriques (page 207)

Les aciers produits dans les fours électriques à arc se distinguent par des caractéristiques mécaniques améliorées par rapport aux aciers fabriqués par d'autres procédés. On ne dispose pas encore de statistiques s'étendant sur une longue période en ce qui concerne le fluage des aciers au carbone et au manganèse. Cependant il ne semble pas qu'il y ait des différences notables sous ce rapport entre des aciers produits dans des fours électriques et des aciers obtenus par les autres procédés classiques. En outre il n'est pas probable que le léger accroissement de la proportion de certains autres éléments affecte défavorablement la soudabilité de ce type d'acier qui est excellente par ailleurs.

La Teneur en Iode des Effluents Gazeux (page 217)

Les effluents gazeux des centrales nucléaires contiennent habituellement une certaine proportion d'iode, que ce soit en marche normale ou en cas d'incidents. Il est difficile d'isoler l'iode de l'effluent car il se présente sous forme de vapeur condensable. Des milieux absorbants liquides ou solides sont généralement utilisés. Les caractéristiques de diverses solutions sont examinées en ce qui concerne le rendement obtenu et les installations nécessaires. Aucun procédé n'est absolument satisfaisant dans son ensemble. L'exemple d'un circuit d'essai d'éléments de combustible sous pression dans un réacteur permet de décrire les principaux points dont il faut tenir compte. Pour l'extraction de l'iode lors de la décompression du circuit, il semble que le système le plus compact, le plus économique et le plus simple soit constitué par un puits de chaleur, deux filtres, un lit de charbon activé et un dernier filtre, le tout en série.

Schweden (Seite 199)

Das Atomkraft-Programm Schwedens ist seit mehreren Jahren bereits im Fluss, jedoch sind definitive Vorschläge erst in etwa 18 Monaten zu erwarten. Zur Zeit existieren drei Pläne: Fortzufahren mit der Benutzung natürlichen Urans und schweren Wassers (in der Hauptsache der Stand der Regierung); einen 50 MW Siedewasser-Typ zu bauen, der von einem privaten Konsortium, das Kraftmaschinen herstellt, befürwortet wird; einen in den gewachsenen Felsen zu setzenden gasgekühlten, graphit-moderierten Reaktor zu bauen, wobei der Fels als Hochdruck-Behälter und Strahlungsschutz verwendet wird, und zwar für das staatliche Kraftamt. Die Industrie ist dabei Erfahrungen in den verschiedenen Zweigen der Kernkraft-Technik zu gewinnen. Die Produktion von Uran aus niedrigprozentigen Erzen wird ebenfalls aktiv verfolgt. Dies gibt einen starken Anreiz zur Annahme von Reaktor-Typen, die natürliches Uran verwenden können.

Finnland (Seite 205)

Die in Aussicht stehende Kraftwerk-Krise in Finnland wird wahrscheinlich wenigstens zum Teil durch den Einsatz der Atomkraft überwunden werden, da die Chancen, dass mehrere Kraftwerke vor Ende 1970 gebaut sein werden, ziemlich gut sind. Finnland hat gegenwärtig ein Ausbildungs-Programm für Personal in Arbeit, um dies zur Vorbereitung der nächsten Entwicklungs-Phase, die den eigentlichen Bau betrifft, bereit zu haben.

Elektro-Stahl für die Kernkrafttechnik (Seite 207)

Stahl, der im elektrischen Lichtbogen produziert ist, weist bessere mechanische Eigenschaften auf, als Stahl, der im Siemens-Martin-Ofen hergestellt wird. Obwohl noch keine Daten, die für längere Zeitabschnitte gelten, über die Kriech-Festigkeiten von C/Mn-Stählen vorhanden sind, so scheint alles doch dahin zu deuten, dass der Unterschied zwischen beiden Stählen gering ist. Es ist unwahrscheinlich, dass die kleine Zunahme von Rëckstënden eine schädliche Wirkung auf die sonst ausgezeichneten Schweisseigenschaften des Stahles ausüben kann.

Befreiung der Gasströme von Jod (Seite 217)

Es ist immer wahrscheinlich, dass die Abfallprodukte von Atomkraftwerken einen in Betracht kommenden Anteil von Jod enthalten, der sogar mit Absicht vorhanden sein kann. Da Jod als Dampf kondensierbar ist, ist die Absonderung schwierig, und das Problem kann nur durch Absorbierung unter Verwendung flüssiger oder fester Stoffe gelöst werden. Es werden die charakteristischen Eigenschaften der verschiedenen Alternativen in Hinsicht auf ihren Wirkungsgrad und die nötige Apparatur untersucht. Eine allumfassende Lösung ist nicht möglich, und als Beispiel zur Veranschaulichung der verschiedenen Kriteria, die geprüft werden müssen, ist ein Prüfkreis aus einem unter Druck im Kern stehenden Brennstoffelement gewählt worden. Um das Jod aus dem Kreis während der Druckentlastung zu entfernen, ist, wie man gefunden hat, das kompakteste, einfachste und wirtschaftlichste System ein System bestehend aus einem Wärme Absorpen, dem zwei Filter folgen, weiter ein Bett aus aktivierter Holzkohle und ein Endfilter.

Suecia (pág. 199)

El programa de fuerza nuclear en Suecia ha estado en una condición fluida durante varios años, pero se espera que se finiquiten propuestas definitivas dentro de unos 18 meses. Tres existen en la actualidad: continuar con conceptos de uranio natural y agua pesada (mayormente una linea del gobierno); construir un tipo de 50 MW de agua hirviente para un consorcio de empresas particulares productoras de energía eléctrica para servicios públicos; construir un reactor moderado a grafito y enfriado por gas empleando roca como el recipiente de presión y la pantalla de blindaje, para el Consejo de Energía del Estado. La industria está ganando experiencia en los diversos ramos de tecnología nuclear. La producción de uranio de minerales de baja ley también se está desarrollando activamente. Hay un fuerte incentivo para la adopción de tipos de reactores que pueden emplear el uranio natural.

Finlandia (pág. 205)

La venidera crisis de abastecimiento de energía en Finlandia ha de ser parcialmente enfrentada mediante la fuerza nuclear y las perspectivas de que se construyan varias centrales de fuerza antes del fin de 1970 son muy posibles. Actualmente Finlandia se está lanzando al desenvolvimiento de un programa de entrenamiento de personal como una preparación para la fase de construcción. Nuestra descripción de la situación en Finlandia incluye una sinopsis de la situación crítica de sus abastecimientos de energía.

Aceros de Horno Eléctrico para Aplicaciones Nucleares (pág. 207)

El acero producido en horno eléctrico de arco posee propiedades mecánicas mejoradas en comparación al acero producido a base del procedimiento de hogar abierto Siemens-Martin. A pesar de que no existen datos recopilados a base de larga experiencia sobre las propiedades de fluencia de aceros C/Mn, las indicaciones son de que hay poca diferencia entre los dos aceros. Poco probabilidad hay de que el pequeño aumento de residuos afectará de una manera adversa la excelente soldabilidad que de otra forma posee este acero.

El Yodo es Extraible de Corrientes de Gases (pág. 217)

Es posible que la descarga proveniente de instalaciones de energía atómica, sea ésta deliberada o accidental, contenga una fracción significante de yodo. Siendo un vapor condensable, su extracción es difícil y el problema puede ser enfrentado mediante el uso de absorbentes líquidos o sólidos. Se examinan las características de las diversas alternativas en términos de la eficacia de su extracción y del equipo necesario. No se puede hallar una solución comprensiva y para ilustrar los criterios que han de ser examinados, se toma un ejemplo de un circuito presurizado de comprobación de elementos de combustible en el interior de un reactor. Para quitar el yodo del circuito durante la despresurización, se llega a la conclusión que el sistema más compacto, sencillo y económico consiste de una pileta térmica, seguida de dos filtros, un lecho de carbón de madera activado y un filtro final.

Technical Papers and Publications

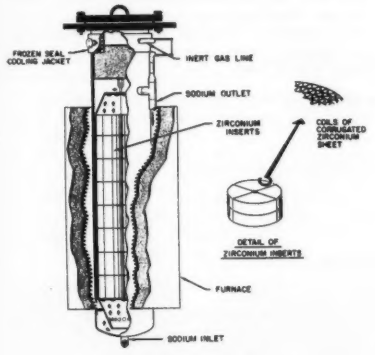
U.S. AEC

NAA-SR-3638. Control of Oxygen Concentration in a Large Sodium System. By R. B. Hinze (Atomics International) (Office of Technical Services, Washington 25, D.C. $1.50).

The report covers the determination of operating characteristics of both cold and hot traps and was carried out on a large (50,000 lb.) sodium system (the initial operation of the SRE). Throughout the test, the oxygen concentration was determined from saturation temperature of the sodium—i.e., the temperature at which sodium oxide is deposited from a sodium system—and then the oxygen concentration determined from the temperature-solubility curve. Saturation temperatures were measured by means of a "plugging" meter. This consisted of a number of small holes in a stainless steel disc, located in a secondary circuit along with a heat exchanger and the necessary flow and temperature instrumentation, the sodium being cooled to the point where the holes became choked with oxide.

Both designs of cold trap utilize a packing of rolls of stainless steel mesh but differ in their method of cooling, the first being cooled by boiling toluene and the second being force-convection cooled by means of tetralin, the reactor service coolant. The hot trap utilized rolls of corrugated zirconium. The efficacy of both cold and hot traps has been well established, it being possible to obtain oxygen concentrations of 8 ppm in the 50,000 lb primary system by means of a cold trap. Hot trapping is even more efficacious, it being possible to lower the saturation temperature to a point at which further readings were impracticable since about 225°F is the minimum possible operating temperature.

There are several interesting features about the results. One is the difficulty of



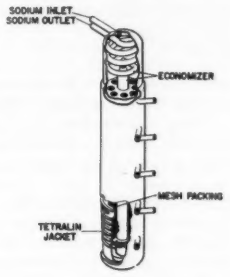
Typical design of hot trap.

incorporating an economizer in the cold trap circuit since the sodium may become saturated with oxygen when shut down for refuelling or modification programmes. On starting up again with the sodium bulk temperature very little above the saturation temperature, plugging of the economizer may occur. Difficulties were also encountered with the boiling-coolant cold trap which, unlike the forced-convection-coolant trap, does not have a uniform temperature gradient throughout. There is a tendency for heavy oxide deposits to form at the coldest spot, thus plugging the trap before it has collected its full quota of oxide.

NAA-SR-4382. HNPF Cold Trap Evaluation. By R. Cygan (Atomics International) (Office of Technical Services, Washington 25, D.C. $1).

This takes the work covered by the previous report NAA-SR-3638 a stage further and covers traps for the SGR under construction at Hallam, Nebraska, tested in a sodium loop, with provision for adding oxygen, first as sodium oxide and, later, as gaseous oxygen. Work done on the SRE has shown that trapping ability is predictable but that the oxide capacity of a trap and the final pressure drop across it are not predictable and the primary object of this series of tests was to ensure that the designs were capable of cold trapping 200 lb of oxide before the pressure drop reached 20 p.s.i.

The two main difficulties likely to be encountered have already been indicated in



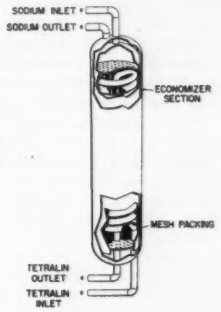
No. 1 design of cold trap, with tetralin jacket.

the previous report, i.e., fouling of the economizer and plugging of one portion of the packing due to non-uniform temperature gradient across the unit, and both these points received special attention in the design of the HNPF traps. No. 1 design was 20-in. diameter and 9-ft long, the lower 8 ft being jacketed with a tetralin coolant jacket and the lower 6 ft section packed with woven stainless steel mesh of a density of 24 lb/cu. ft. The economizer is a 6 in. tube, 6 ft 6 in. long with 3½ turns of 2⅜-in. tubing at the upper end. The flow can be seen from the diagram. The jacketing was originally intended to be operated in four separate sections but they were, in fact, run in series.

The second design utilizes an internal cooling coil for the tetralin, the economizer being arranged by double-shell construction of the vessel, the inner shell being open at the bottom. The diameters of the two shells are 22 in. and 20 in. and the length approximately 8 ft.

Both designs are required to operate under two different conditions, 40 gal/min at 350°F (corresponding to clean-up conditions) and 10 gal/min at 607°F (corresponding to operating conditions).

Up to about 100 lb of oxide, the pressure drop across each trap was moderate. With more than this quantity the pressure drop across the traps increased rapidly but at the same time the pressure drop across the external system also increased rapidly, so



No. 2 design of cold trap, with tetralin cooling coil.

that the rated flow could not be maintained. Shutting-off the oxygen resulted in a pressure drop throughout the system. Oxide reached 200 lb with oxygen being introduced at discrete intervals, the final pressured drops with 200 lb of oxide in the traps being 6.7 p.s.i. for design No. 1 and 6.0 for design No. 2. It was found that the effectiveness of No. 1 economizer was better than that of No. 2 design and that there is considerably less deterioration as the oxide content of the trap approaches full capacity. On the other hand the simiple Y design features in No. 2 results in low fabrication costs so that the choice is between initial cost or thermal economy.

TID-8516. Civilian Power Reactor Programme. Part I: Summary of Technical and Economic Status as of 1959 (U.S. Government Printing Office, Washington 25, D.C. $1).

A concise and objective report giving a general picture of reactor development in the U.S. For each reactor type, from the pressurized water to the plutonium recycle project, a summary of the present status is given, together with the operating experience obtained, a construction schedule of reactors building or in operation, and an economic survey. This occupies more than one half of the total 140 pages of the report, the other major item being a survey of the status of general engineering research and development (nuclear technology) on fuels, cladding materials, fuel fabrication, irradiation testing, chemical reprocessing, components, environmental investigations and effluent control, physics, and reactor safety. The report is intended as a general summary. Part II will be entitled "Economic Potential and Development Programme." Part III consists of a series of reports for each reactor and Part IV will be the specific programme recommendations for each reactor type. Roughly speaking, then, this report is a summary of Part III, which will later be issued as TID-8518.

O.E.E.C.

(European Nuclear Energy Agency)

Second Report on the Activities of the Agency.

This report covers the activities of the European Nuclear Energy Agency in the 18 months which have elapsed since the presentation of their first report. Details are given of the setting up of the international company, EUROCHEMIC, for the chemical processing of irradiated fuels and a full account is given of activities during the interim period. The Halden boiling heavy water reactor project is another item covered. It should be noted, by the way, that the Halden project is not an international company in the same way as EUROCHEMIC, since the reactor remains the property of the Norwegian Institute. A complete text of the agreement concerning the high temperature gas cooled reactor project DRAGON is also given.

Other important items are the terms of reference of the European American Nuclear Data Committee (on nuclear cross sections) and the decision of the Council on the adoption of radiation protection norms with appendices giving maximum permissible doses and table of maximum permissible concentrations of isotopes in drinking water and air inhaled. A further section gives estimates of nuclear energy production in Europe and summaries of the programmes of the O.E.E.C. countries. Tables of research reactors and nuclear power stations, building, projected, and in operation, are also given, together with a map of the O.E.E.C. countries, showing the locations of these reactors.

AEA

AERE-R 3067. Some Aspects of Fires in Glove-boxes. By C. Jackson, T. W. Hodge, D. H. Swingler, A. J. Smith. (H.M.S.O. 4s. 6d.)

Details are given of a series of tests which have been carried out to determine the stresses to which a glove box would be subject if a fire or explosion occurred within it. Both coal gas and benzene were used in simulating fire and explosions to determine not only what would happen with positive pressures while the fire was burning, but also the effect of negative pressures after the fire had been extinguished. A series of tests was also carried out on various types of fire extinguisher.

Space does not permit of detailing the results of the tests, but there are several interesting features, amongst which are that if gloves are not clamped they may blow off; if clamped they may either burst or withstand the pressure according to conditions (in one particular case a glove was inflated to an estimated size of 6 ft long by 3 ft diameter without bursting). If bungs are in place, the front panel of the box may be either sucked in or blown out, since in certain circumstances it may be possible to have an inward pressure of up to half a ton on the front panel.

AEEW-N 29. A Vehicle-mounted Scintillation Ratemeter for Environmental Survey. By I. W. Cavell (Winfrith).

Describes experimental work carried out at Winfrith on rapid methods of making background surveys. The instrument was a type 1413A Geological Survey ratemeter, battery operated and transistorized with a sodium iodide crystal detector, which on its most sensitive range will measure 0.15 μr/h; this was coupled to a 1487A recorder. The vehicle was a Land-Rover.

Unlike previous surveys, where the detector has been fitted inside the vehicle, it was mounted on a 10 ft pole on the offside of the vehicle's front bumper. It has thus a considerably larger field of view, not being shielded by hedges or by the bodywork of the vehicle. It is also less sensitive to changes in the road surface material. Should the vehicle become contaminated by being driven through fallout, this would have a smaller effect on the detector readings.

A full account of the results of tests including typical traces at various speeds of vehicle is given. It is concluded that 20 m.p.h. is a convenient speed for carrying out this work.

AERE-R 3161. A Torus for the Arc-testing of Materials. J. T. Maskrey, R. W. Barnfield. (H.M.S.O., 5s.)

Describes the construction of a toroidal discharge tube to provide a source of plasma for testing metallurgical specimens for their arc-resistant properties.

AERE-R2998. Thermal neutron cross-sections of several isotopes. By J. F. Raffle. (H.M.S.O. 7s.)

A detailed account of measurements of the fission cross sections of U^{233}, U^{235}, Pu^{239} and Pu^{241}. Measurements were made for 2200 m/sec neutrons, thermal and pile neutron spectra.

AERE-R3153. Physics measurements during the commissioning of PLUTO—Neutron flux distributions. By C. J. England and S.B. Wright. (H.M.S.O. 12s.)

A report giving details of flux measurements made as part of the start-up programme of this reactor. As it is not possible to give a complete energy spectrum, fluxes are treated as falling into one of three distinct energy groups; thermal, epithermal and fission, without defining precise energy limits of each group. Typical thermal neutron fluxes for the unperturbed reactor (i.e., without experiments loaded in the experimental holes) vary from 1.6×10^{13} for the lowest reading taken, to 1.7×10^{14} for the flux-scanning hole in one of the fuel elements, at 10 MW thermal power. There are some 65 curves of flux distribution in this report.

AERE-R2954. Environmental Survey from the Air. By D. Williams and R. S. Cambray. (H.M.S.O. 6s.)

Describes the extension of mobile gamma-emission surveys to include aerial work, the methods used, and the practical considerations of such work. The aircraft used was a Hunting Percival Prince, and the instrumentation consisted of a type 1531B aerial survey instrument, with three scintillation counter heads, each containing a thallium-activated sodium iodide crystal, optically coupled to an E.M.I. 9530B photomultiplier tube. An APN1 radio altimeter was arranged for simultaneous recording so that count rate and height could be correlated. An air survey camera was used for recording flight tracks. The report includes results of an aerial survey around the Harwell area, with an analysis of the results, and an evaluation of the technique with reference to the detection of small concentrations of I^{131}.

AERE C/R 2855. The results of Radiation Chemical Measurements during the early operational period of DIDO. By A. R. Anderson and W. R. Marsh. (H.M.S.O., 4s.)

The main chemical problems in a heavy water reactor are the decomposition of the heavy water and the formation of nitric acid under the influence of radiation. This report gives the results of experiments carried out during the DIDO start-up period.

It has been found that the rate of production of nitric acid is about 1 μM per day at full power and it is not anticipated that any trouble will be experienced with the ion exchange units which should have a life of several months. So far as the efficiency of the Baker-Platinum recombination unit is concerned the efficiency, as measured by the decrease in oxygen concentration, is over 90% when excess deuterium is present. Due to the removal of oxygen and the production of deuterium by corrosion, there is an oxygen deficiency in the gas circuit. It is thus necessary to inject oxygen periodically, to maintain deuterium concentration at less than 0.4 per cent.

MEETINGS

April 26.—The Institution of Chemical Engineers (Manchester), "Sealing against pressure and vacuum."

May 2.—The Institution of Electrical Engineers (at the Cavendish Laboratory, Cambridge), "Fundamental Particles," Professor O. R. Frisch.

May 2.—The Institute of Physics (at Institution of Mechanical Engineers), Joint Conference with Societe Francaise de Metallurgie.

May 3.—The Institute of Metals (Church House, Great Smith Street, London, S.W.1), "The Determination of Gases in Metals."

May 3.—The Institution of Electrical Engineers (Savoy Place, London, W.C.2), "Teaching and Learning Machines," C. E. G. Batley.

May 4-6.—The Institution of Chemical Engineers (The Dome, Brighton), "International symposium on distillation."

May 16.—The Institution of Electrical Engineers (at the Technical College, Stafford), Annual General Meeting, "The Characteristics and Protection of Semiconductor Rectifiers," D. B. Corbyn, N.L. Potter.

May 17.—The Royal College of Science and Technology (Glasgow), Symposium on Nuclear Reactor Containment Buildings and Pressure Vessels.

May 20.—The Institution of Electrical Engineers (Savoy Place, London, W.C.2), "New Semiconductor Devices and their possible Applications," A. F. Gibson, G. King.

May 27.—Non Destructive Testing Society (Reid Knox Hall, British Institute of Radiology, 32 Welbeck Street, London, W.1.), "Site Inspection on Overseas Projects," Mr. C. C. Bates.

Personal

Sir Leslie Gamage

Mr. H. McGlyn

Mr. G. B. G. Potter

Mr. J. W. Ringrose

Appointments

Sir Leslie Gamage re-elected as president of the British Electrical and Allied Manufacturers' Association. **Mr. W. K. G. Allen** re-elected as chairman of the council, and **Mr. A. M. Browne** as vice-chairman.

Mr. W. K. Hutchison as a member of the Scientific Advisory Council.

Dr. R. L. P. Berry to the board of I.C.I., Metals Division.

Mr. H. C. Drayton to the board of British Insulated Callender's Cables.

Lord Plowden as chairman of Venesta Foils.

Mr. W. F. Cartwright as president of the Iron and Steel Institute.

Dr. J. N. Aldington as chairman of London Electric Wire, **Mr. S. B. Klein** as managing director.

Mr. C. R. Newton to the board of Cockburns (Springs).

Mr. J. W. Ringrose as chief applications engineer of Semiconductors.

Mr. L. C. Lebar as project and technical sales engineer of Electronic Machines.

Dewrance branch appointments are: **Mr. R. W. C. Jeffrey,** manager, Scottish office; **Mr. J. Best,** manager, Manchester office; **Mr. L. Walker,** manager Bristol office; and **Mr. D. A. Robins** as his assistant.

Mr. R. P. Janion as sales engineer of the switchgear division at the Witton Works of G.E.C.

Dr. D. H. Follett as director of the Science Museum. **Mr. D. Chilton** becomes keeper of the department of electrical engineering and communications of the Science Museum.

Mr. C. J. Hind as engineering director of Ruston and Hornsby.

Mr. F. L. Turnbull as general manager and to the board of Armstrong Whitworth (Metal Industries).

Mr. B. S. Bass to the board of Dewrance. **Mr. A. Brown** becomes sales manager (home); **Mr. A. C. Jones,** sales manager (export) and **Mr. C. G. Seeds,** sales manager (controls division).

Mr. L. C. Lebar

Mr. S. G. Spooner

Mr. G. B. G. Potter as director and co-ordinator of Smiths Aviation research and engineering and **Mr. K. Fearnside** as director of research and engineering of Smiths Aircraft Instruments.

Mr. S. G. Spooner as works manager of Marconi Instruments.

Mr. E. N. Griffiths as vice-president of the British Engineers Association.

Mr. C. F. Lindskog as managing director of Skefco Ball Bearing.

Mr. G. Conradi as president of the Electrical Wholesalers Federation.

Major V. B. J. Seeley to the board of Acrow Engineers.

Sir Thomas Williamson and **Mr. H. Douglas** as part-time members of the Iron and Steel Board.

Mr. C. W. Spangle as managing director of Honeywell Controls.

Mr. I. Bailey as deputy chairman of Mond Nickel and Henry Wiggin, and **Mr. E. Vaughan** to the boards of both companies.

Mr. W. C. Handley, chairman; **Mr. W. F. Randall,** deputy chairman and managing director; **Dr. G. A. V. Sowter,** commercial director; **Dr. H. H. Scholefield** as technical director of the newly formed Telcon Metals.

Mr. G. F. Ashford as deputy chairman of the chemical group of The Distillers Company.

Mr. I. B. Cooke as director and general manager of Industrial Fan and Heater.

Dr. C. J. Dadswell as chairman of Davis and Lloyd, a subsidiary of English Steel. **Mr. C. Muirhead** becomes managing director.

Mr. G. Wright as chief engineer of Electrothermal Engineering.

Mr. F. E. Wilson as managing director of B. Elliott (Machinery).

Mr. J. M. Kershaw as alternate to **Mr. T. P. Berington** on the board of Monsanto Chemicals.

Mr. J. Samuels as works director of Winston Electronics.

Mr. W. Padley to the board of Metal Industries.

Mr. H. W. Wright as head of the electrical department of Keith Blackman.

Sir Samuel H. Brown to the board of British Columbia Power Corporation.

Mr. W. Innes as chief accountant of AVO.

Mr. H. McGlyn as quality control engineer of the Brighton factory of West Instruments.

Mr. V. A. Plumley as manager of Bailey Meter Division of Steam and Mining Equipment.

Mr. W. H. Coates as a joint managing director of British Chrome and Chemicals.

Mr. C. I. Rutherford as production director of I.C.I. fibres division.

Mr. E. F. D. Webb as engineering manager of Hagan Controls.

Mr. L. Davies to the board of Guest Keen and Nettlefolds.

Mr. L. R. E. Appleton as managing director of Fairey Engineering and **Mr. P. J. Duncton** as general manager, Heston.

Mr. G. Liley to the board of British Lead Mills.

Overseas

Prof. F. Ippolito as chairman of the advisory committee of the Euratom Supply Agency.

Prof. C. Salvetti of Italy as director of the IAEA division of research and laboratories.

Mr. A. M. Weinberg, director of Oak Ridge National Laboratory, to serve on President Eisenhower's 21 member Science Advisory Committee.

Dr. R. C. Allen as head of the newly formed reactor physics group at Atomics International.

Mr. J. L. Bloom as project engineer for the advanced SNAP programmes of The Martin Company.

Mr. R. G. Boyd, Mr. F. J. Drewes and **Mr. H. C. Holmes,** as vice-presidents of Kaiser Aluminium and Chemical.

Mr. C. H. Sommer as president of Monsanto Chemical.

Mr. G. S. Trimble as vice-president for advanced programmes of The Martin Co.

Mr. G. S. Vermilyea as president of Nems-Clarke, a division of Vitro Corporation. **Mr. H. Bottomley** as regional manager in charge of the Treco division.

Obituary

Nuclear Engineering regrets to report the death of:—

Mr. B. Baden, chairman and joint managing director of Matthew Hall on April 4 at the age of 65.

Retirements

Sir Henry Jones from the Scientific Advisory Council.

Mr. R. T. Redfern as managing director of Bryan Donkin.

Mr. J. W. Plowman from the board of Dewrance.

Mr. S. S. Scott as chief personnel officer of the CEGB.

Tours

M. E. G. Jones of Pollard Bearings to the Far East and Australasia.

Mr. J. G. Window of QVF to Spain, Portugal and Italy.

Industrial Notes

H.R.H. The Duke of Edinburgh seen being introduced by Sir Edward Thompson, chairman and joint managing director of John Thompson, to Lord Chandos, chairman of A.E.I., at a film show by John Thompson, featuring the activities of the company in the building of Berkeley and Dounreay.

E.M.I. Electronics have supplied a variable time delay unit for assisting in the design of coolant systems for reactors to Centro di Studi Nucleari at Ispra near Milan. The unit accurately simulates the delays occurring in the flow through a coolant system and can be used with an analogue computer to provide accurate time delays.

Pantak have concluded an agreement with Sierex for the marketing and servicing of the Siemens mobile 15 MeV industrial betatron. In use for radiography an image enlargement of four times can be made.

Details of the post-graduate course in nuclear technology (chemical) to be held at the **Imperial College of Science and Technology,** 1960-61, have now been published. Satisfactory completion of the course will qualify students for the award of the Diploma of Imperial College and the Department of Scientific and Industrial Research have said that the course is acceptable to them for tenure of Advanced Course Studentships.

The ninth **Electrical Engineers Exhibition** was held at Earl's Court from April 5-9. Sponsored by the Association of Supervising Electrical Engineers the exhibition was opened by Mr. Reginald Maudling, President of the Board of Trade.

Nuclear Enterprises are supplying a carborne scintillometer to the Swedish Atomic Energy Authority. The equipment uses a four-channel recorder and is for uranium, potassium and thorium prospecting.

The British Association of Corrosion Engineers has been elected a member of the European Federation of Corrosion.

Electric Resisting Furnace are now manufacturing quenching oils containing Quenzine, a formulation of wetting oils and other ingredients developed in the U.S. by **Aldridge Industrial Oils.**

John Bass announce that they have been awarded a Gold Medal for the second time for their Man-Cleaner Unit at the Brussels Annual International Exhibition of Inventors.

High Voltage Engineering have been awarded a development contract for the contruction of an intense ion source for acceleration and injection of hydrogen ions into the DCX thermonuclear machine at Oak Ridge. The device will be capable of producing over 25 milliamperes of mass-analysed singly-ionized molecular hydrogen.

Solartron-John Brown Automation is the name of a newly formed company for the designing and manufacture of systems of automation for industry. The company have the exclusive rights outside America to the Gumpertz Automatic Warehousing system.

Telcon Metals is the name of a new company formed by **British Insulated Callenders Cables** to assume the responsibility for all the activities of the metals division of **Telegraph Construction and Maintenance.**

Ferranti are to supply the U.S.S.R. with £300,000-worth of high-voltage testing equipment. The equipment, which will be used in testing cables, include two d.c. testing units, one giving an output of 2 MV, six a.c. units and one 3.6 MV impulse generator.

Radiation Counter Laboratories announce the manufacture of a new low-cost GM counting system. The equipment includes a vertical iron shield with lucite mount for end window halogen quenched detectors.

George Kent announce that now, having sold the interest, assets and production capacity of the steering gear division to Cam Gears they will concentrate on industrial instrumentation and process control.

The regulations for admission to the classes of graduate and associate membership of the **Institution of Chemical Engineers** have been revised.

A new publication, B.S.3228:1960, by the **British Standards Institution** forms part of a series of procedures for obtaining the data necessary to determine the properties of steel at elevated temperatures.

A standardization for pipe hangers has been submitted by the **Engineering Equipment Users Association** to the British Standards Institution.

A new building for the **Coil Spring Federation Research Organization** of the Department of Scientific and Industrial Research was opened on March 24 by Sir Harry Melville.

Telemechanics have recently appointed **Conway Electronic Enterprises** of Toronto as their Canadian agents and **M. Rietveld** of Rotterdam as their Dutch agent.

The contract for the construction of a laboratory for radioactive solids for the **Institute fur Reaktorwerkstoffe** has been awarded to **Leybold Hochvakuum Anlagen** of Cologne. The laboratory will be built at the nuclear research centre near Julich and is expected to be completed by the end of next year.

The 1960 Scottish conference of the **British Institute of Management** was held from April 29-30.

Texas Instruments have made available 11 new series of transistors, rectifiers and resistors, claimed to be the highest frequency transistors obtainable in this country.

SIMA announce that they now have a total of 149 full members and 30 associate members. Latest additions are: **Wilkinson Sword, Claude Lyons, Bruce Peebles** and **Nagard** as full members, and **Amplivox** and **B. and R. Relays** as associate members.

The Electrical and Electronic Manufacturers Joint Education Board has been established to co-ordinate all aspects of education and training on behalf of allied industries.

The April-October, 1960, prospectus of the **School of Welding Technology** has now been published. (54 Princes Gate, Exhibition Road, London, S.W.7.)

English Steel Forge and Engineering have made four pressure steam distributor drums, the longest one-piece hollow forgings ever to be made in the U.K., for the CEGB's Thorpe Marsh power station.

Thos. W. Ward have acquired the entire share capital of **Anchor Insulating.**

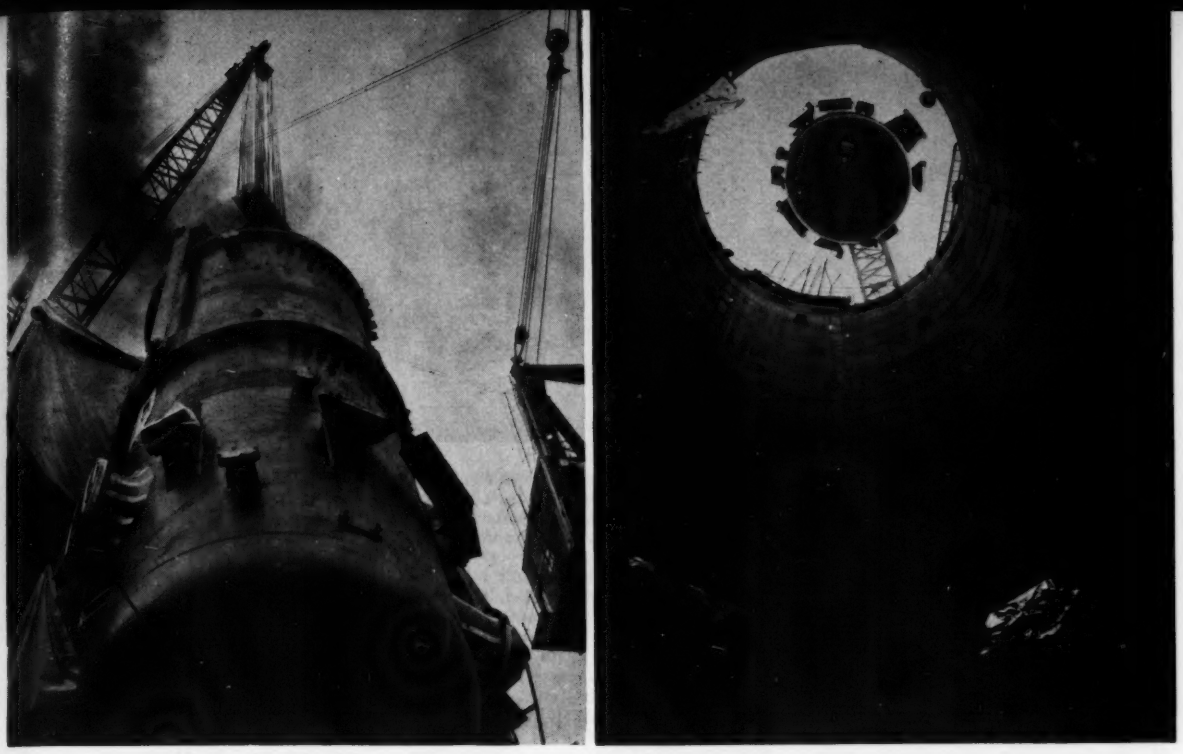
Recent changes of names, addresses and telephone numbers are:—

The service department of **Research and Control Instruments'** new telephone number is Battersea 8641.

Hagan Controls have moved to 14 Grosvenor Place, London, S.W.1. Tel.: Bel 6382.

Boüellat Engineering have changed their name to **Vauxhall Boiler.**

Klaxon's London sales office is now at 189 Drummond Street, London, N.W.1. Telephone: Euston 4102.



The first of four heat exchangers for the advanced gas-cooled reactor under construction at Windscale being lifted and lowered into position within the secondary shield inside the containment vessel.

World News

International

A PANEL has been convened by the IAEA to help in developing costing methods to serve as a guidance to less developed countries wishing to assess the possibilities of using nuclear power. Chairman is Prof. F. Ippolito, secretary-general of the National Committee for Nuclear Research in Italy.

REQUESTS FOR ASSISTANCE in measuring environmental radioactivity have been received by the IAEA from the United Arab Republic and the Sudan. Consideration is also being given to a proposal that a Middle East Regional Radioisotope Centre be established in Cairo.

TEN COUNTRIES are to receive assistance and equipment from the IAEA totalling $47,200. The countries are Afghanistan, Austria, Brazil, Iran, Iraq, Korea, Philippines, Turkey, Venezuela and Yugoslavia.

APPROVAL HAS BEEN GIVEN by the Board of Governors of the IAEA to a proposal that a preliminary technical assistance mission be sent to several countries in the Middle East and Africa. Countries which have requested a visit are Greece, Morocco, Tunisia, Sudan, the Ivory Coast and the Federation of Mali.

United Kingdom

THE FIRST SERIES of experiments at Dounreay have now been completed and the reactor is expected to be shut down for about three months while changes are being made to the core. It is expected that the second loading of elements will be all niobium-vanadium clad. The reactor was operated at 50kW for the first experiments.

THE PUBLIC INQUIRY to use Oldbury as a site for a nuclear power station was held last month.

Australia

A PROFIT of nearly £A2 million has been made by the Mary Kathleen Uranium Mine after its first full year of operation. Situated in north-west Queensland, the mine has produced nearly 1½ million lb of uranium oxide. Current contracts run until 1964.

THE GOVERNMENT is being urged by members of Parliament to consider seriously the building of a nuclear power station near Melbourne and Adelaide as soon as possible.

Brazil

AN AGREEMENT has been signed by the National Commission for Nuclear Energy appointing Kennedy and Donkin of the U.K. as consulting engineers for a nuclear power station project. This firm have also been asked to arrange for American consultants to work with them in preparing invitations to tender for the plant in the autumn of this year. It is expected that the selection will be made about mid-1961 and it is believed that the plans are to construct a 150-200 MW station at a site on the River Mambucaba, south of Rio de Janeiro.

The Austrian Federal Chancellor, Mr. J. Raab, visiting the IAEA laboratory, under construction at Seibersdorf, near Vienna. With him are Mr. Sterling Cole, director general, on his right, and Dr. H. Seligman, deputy director general, on his left.

Canada

A FIVE-YEAR CONTRACT has been signed by Atomic Energy of Canada with AMF (Canada) for the development of nuclear fuel elements for Canada's nuclear research and power programmes. AMF have a fuel fabrication facility at Port Hope. The company are undertaking a programme to develop designs and processes for the fabrication of Zircaloy-clad uranium dioxide ceramic fuel for CANDU.

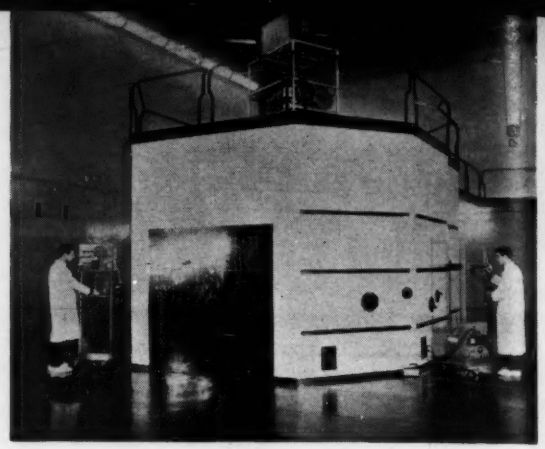
A LETTER has been sent to various organizations by the Steering Committee of the proposed Canadian Nuclear Association, requesting expressions of interest. Should satisfactory answers be received, the Committee propose taking immediate steps to establish the Association. Address of the Steering Committee is P.O. Box 475, Toronto, Ontario.

Denmark

AN INTERNATIONAL COURSE in plasma physics is to be held at the research centre at Risø of the Atomic Energy Commission from August 1-12. The course will cover the principal fields of theoretical and experimental plasma physics with special regard to the present interest in controlled thermonuclear research. Lectures will be held at graduate level but will be accessible to non-specialists in this field as well.

Egypt

A NUCLEAR EXHIBIT will be staged by the U.S. AEC in Cairo from May 8-30.



The 5 MW solution-type research reactor at the Enrico Fermi Study Centre in Milan built by Atomics International. The reactor recently began operating.

The exhibition will be split into two parts, one of a technical nature and one of general interest for the public. A portable UTR research reactor built by Advanced Technology Laboratories will be on display. The AEC plan to hold the same exhibition in Argentina, Brazil, Peru and Venezuela.

France

THE NEXT NUCLEAR power station to be started in France will be an 80 MW heavy-water moderated and cooled by compressed carbon dioxide, type using natural uranium. The plant will be built near Borlaix and work is expected to begin at the end of this year or early in 1961.

AN AGREEMENT for collaboration in the peaceful uses of nuclear energy has been signed with the U.S.S.R. It includes the interchange of scientists and information and possibly joint projects in fusion, radiopathology and manufacture of tracers for radiobiology.

West Germany

EXPENDITURE on the nuclear energy programme will total £209 million during the next five years according to Herr Siegfried Balke, Atomic Minister. The money will mainly be spent on research and training.

GOVERNMENTAL SUPPORT is to be given to two ship propulsion studies. One is a 70 MW pressurized water type by Siemens and Howaldtswerk - Hamburg and the other is a 60 MW boiling water type by AEG and Deutsche Werft-Hamburg. It is expected that the Government will pay half the cost of each (expected to be DM3 million). A Government decision is expected this summer on the support for the Interatom / G.K.S.S. organic ship project.

TWO OTHER SHIP propulsion systems are being investigated; a gas-cooled type by Babcock and Wilcox with Blohm and Voss-Hamburg (20,000 s.h.p.) and a pebble-bed type by BBC-Krupp with A. G. Weser-Bremen (10,000 s.h.p.).

PLANS HAVE BEEN MADE by Siemens to construct a 50 MW pressurized heavy water reactor using natural uranium fuel. The plant is expected to cost about DM100 million and it is hoped that Government finance will be made available.

India

RECOMMENDATIONS by the Atomic Energy Commission are that India should make provision for 1,000 MW of nuclear power in the Third Five-year Plan. At present only one station of 250 MW, for construction near Bombay, is being planned. This plant is expected to be natural uranium fuelled and it is also expected that the U.S.S.R. will be among the bidders to construct the plant. Recommendations for the second power station are that it should be in the Delhi Bhakra Nangal area and consist of two 150-MW reactors using enriched uranium fuel. It is also hoped to set up facilities for the production of 100 to 200 tons of uranium a year.

Indonesia

TWO RESEARCH REACTORS are likely to be installed by next year. The U.S.S.R. have promised to supply one and talks are being held between Indonesian and U.S. authorities for the other.

Italy

A COMPANY for the manufacture of nuclear fuel materials, Italatom, has been formed in Milan. One Italian concern, Societa Montecatini, one South African, Anglo-American Corporation and two American, Englehard Industries and Mallinckrodt have formed the company. Italatom will enter the market for fuels in Italy and other countries.

New Zealand

THE POSSIBILITIES of several senior scientists and engineers gaining experience in U.K.AEA establishments will be investigated by Mr. J. E. Adamson of the AEA administrative staff who is at present in New Zealand. The secretary of the New Zealand Atomic Energy Committee has said that those selected would spend three years in the U.K.

RESEARCH EQUIPMENT worth £110,000 will be supplied to nuclear institutions by the U.S. The equipment will be installed at the universities of Auckland and Canterbury and the Institute of Nuclear Sciences and is expected to be completed by the end of this year.

March, 1960

Site Licence No.1.

NUCLEAR INSTALLATIONS (LICENSING AND INSURANCE) ACT, 1959
(7 & 8 Eliz.2.c.46)

NUCLEAR SITE LICENCE

Merlin Reactor

1. The Minister of Power (hereinafter referred to as "the Minister") in pursuance of subsections (1) and (4) of section one of the Nuclear Installations (Licensing and Insurance) Act, 1959, hereby licenses Associated Electrical Industries, Limited, 33, Grosvenor Place, London, S.W.1. (hereinafter referred to as "the licensee") to use the site described in Part I of the First Schedule to this licence and coloured pink on the plan annexed hereto (hereinafter referred to as "the site") for the purpose of operating the plant described in Part II of that Schedule, being plant falling within paragraph (a) of the said subsection (1) hereinafter referred to as "the plant").

2. This licence is granted subject to the conditions contained in the Second Schedule hereto.

3. This licence shall come into force on the first day of April, nineteen hundred and sixty.

Dated this twenty-fifth day of March, nineteen hundred and sixty.

D. H. Crafton

An Assistant Secretary to the Ministry of Power

The first licence for a reactor granted in the U.K.

Pakistan

PLANS for the peaceful uses of nuclear energy in Pakistan are being discussed by Dr. I. H. Usmani, chairman of the Atomic Energy Commission and Mr. M. Patterson, chairman of AMF. The company have drawn up a master plan for a nuclear research centre in Pakistan.

Puerto Rico

A PUBLIC HEARING to consider the safety aspects of the nuclear power station to be built at Rincon has been held. The power plant will be a 16.3 MW boiling water type producing superheated steam within the core and is expected to cost $11 million.

Rhodesia

THE OFFER TO BUY chemical concentrates containing uranium oxide from mines in the Rhodesian Federation has been withdrawn by the U.K. AEA. The offer was made three years ago.

South Africa

A DECREASE in uranium exports took place in January and February of this year. The total amounted to £7,990,000 as opposed to £8,500,000 for the corresponding period last year.

A PILOT PLANT to produce nuclear-grade uranium metal and compounds suitable for fuel fabrication is to be built in Johannesburg and is expected to begin operating before the end of the year, according to an announcement by the Atomic Energy Board. The plant will be capable of producing 100 tons of metal a year and will be operated jointly by the Atomic Energy Board and Chamber of Mines at the Government Metallurgical Laboratories.

USSR

THE DISCOVERY of a new nuclear particle, a positively charged anti-sigma hyperon, has been announced by the Joint Nuclear Research Institute in Dubna near Moscow. The discovery of the particle was made possible by extensive experimental work involving the study of 40,000 pictures taken by means of a propane bubble chamber bombarded by a synchro-phasotron.

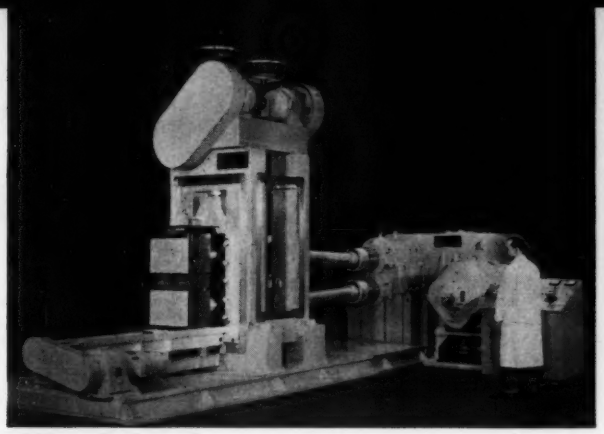
WORKING ELECTRIC MODELS, showing reactor processes, chain reactions and heat production are on show at the Moscow Polytechnical Museum. The models include one of a nuclear power station, one-fortieth in size.

U.S.A.

TOTAL STATISTICS on domestic uranium production for the last six months of 1959 have been announced by the AEC. Ore reserves were estimated to amount to 86 million tons and ore stockpiles stand at 1,500,000 dry tons.

Reserves in New Mexico are still more than twice the rest of the total reserves, viz: 55,700 tons U_3O_8.

THE SAFETY ASPECTS REPORT on the boiling water power station to be built by Pacific Gas and Electric at Humboldt Bay has been filed by the Advisory Committee on Reactor Safeguards. The public hearing for the granting of licence for the station was held during April.



A combination rolling mill for remote control operation in glovebox enclosures for plutonium alloys built by Loma Machine for installation at the Hanford Works of General Electric.

A REPORT on the safety aspects of the boiling water power reactor which is to be built at Big Rock Point by Consumers Powers, has also been filed by the Advisory Committee on Reactor Safeguards.

CONTROL ROD DRIVES for the heavy water components test reactor at the AEC's Savannah River Plant are to be made largely by General Electric. They will comprise 11 of the 12 peripheral drives, a cluster of six positioned in the centre of the core and five of the six safety rod drives. They will all be of the gear-and-rack variety.

SPERT II, a versatile facility developed for studying nuclear safety, achieved criticality on March 11 at Idaho Falls. The reactor was built by Paul Hardeman at an estimated cost of $4 million.

CRITICAL TESTS are reported by The Martin Company to be under way on the PM-1 reactor being built for the U.S. Air Force for installation at Sundance, in Wyoming. A test assembly of 127 tubular fuel elements went critical on March 17. The walls of the elements contain a cermet of highly enriched uranium dioxide and stainless steel with inner and outer cladding of 347-type stainless. Each tube is $\frac{1}{4}$ in. in diameter and 36 in. long with an active length of 30 in.

PROPOSED REGULATIONS to formalize radiation safety requirements for persons using sealed sources of by-product material in radiography have been announced by the AEC. The regulations are designed to minimize the need for placing special requirements in each radiography licence. To date, 420 radiographers have been licensed by the AEC.

FINAL CONTROL ROD drive mechanism for the *N.S. Savannah* has been completed by General Electric. The last 21 control rod drives have now been shipped to Babcock and Wilcox, the major contractors.

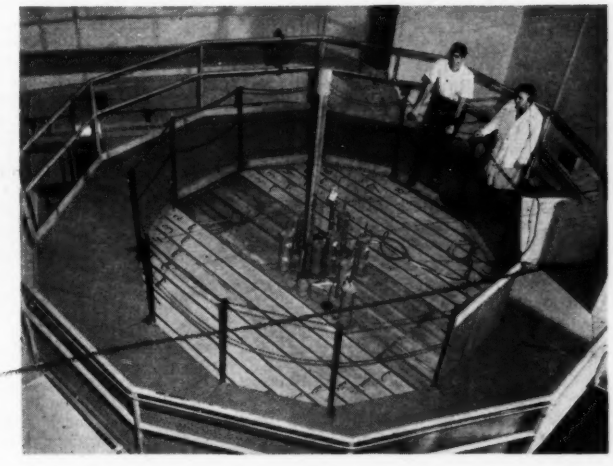
EXPERIMENTAL nuclear rocket reactor tests will be undertaken this summer in two phases. The first will be the ground operation of an experimental engine and the second will be the flight test of a rocket engine.

IT IS PROBABLE that the nuclear rocket system capable of boosting a space ship on a round trip to Mars will use cryogenic liquid hydrogen as propellent and a light-weight, unshielded gas-cooled reactor as the heat source, according to a paper entitled "Nuclear Rocket Environment." The paper has been prepared by Aerojet engineers.

IT IS PREDICTED that research and development work in the AEC's major laboratories will increase in volume over the next ten year period. A report shows that the laboratories employ 42,000 people today and have an annual operating budget of $666 million excluding weapon expenditures.

MAINTENANCE AND SERVICE for the *Savannah* will be carried out by the Todd Shipyard Corporation. The firm will also handle the berthing and servicing of the barge *N.S.V. Atomic Servant*, now under construction.

CRITICALITY WAS REACHED on March 26 by the Tower Shielding Reactor II, at Oak Ridge. The reactor is a tank-type, heterogeneous light-water moderated and cooled, and designed to operate at 5 MW.



A sodium graphite critical assembly which is now operating at the Los Angeles field laboratory of Atomics International. The assembly will provide data for determining fuel requirements for the sodium graphite reactor for the 75 MW Hallam nuclear power facility in Nebraska.

NEW BOOKS

Nuclear Fuel Elements. Edited by Henry H. Hausner and James F. Schumar (409 pp. 192 illus. Reinhold Publishing Corporation, New York, and Chapman and Hall, Ltd., 37 Essex St., London, W.C.2. 100s.)

The fuel element is easily the most important single item of any nuclear power station. In effect, a reactor is designed around its fuel; the economics of fuel processing are, in fact, the economics of nuclear energy. This book—probably the first to be devoted to this subject alone—is an edited collection of the papers presented at the First International Symposium on Nuclear Fuel Elements, held at Columbia University in 1959 and, therefore, contains more concentrated experience and "know-how" than could possibly be acquired by a single author.

Commencing with general surveys of present and future prospects, the book turns to engineering for low-cost fabrication, and to fabrication techniques themselves. Uranium, and uranium-alloy elements are considered in detail, followed by a chapter on the uranium-zirconium hydride elements as used in TRIGA. Following a chapter on the use of thorium, plutonium is considered, together with a number of plutonium alloys, and materials based on plutonium oxide and carbide. Tubular dispersion elements, high-temperature and ceramic elements are well documented.

Many of the above-mentioned chapters deal with several reactors utilizing the same type of fuel. More specialized are chapters on fabrication problems of the APPR fuel plates, and the ISNSE elements for low-power research reactors. French developments in ceramic fuels are described, as are the problems met in fabrication of the metallic elements for EL3 at Saclay, while U.K. experience covers all the gas-cooled reactors at present building and projected. More general chapters deal with overall problems such as the high-temperature creep of uranium-loaded graphite, corrosion in water, and behaviour under irradiation.

In addition to the references given at the end of each chapter, there is a general bibliography containing nearly 500 items of published information. A complete specification written for the APPR is also included as an appendix, as a guide to fuel element specification. N.E.T.S.

Boiling Water Reactors. By Andrew W. Kramer. (592 pp., 292 illus. Addison-Wesley Publishing Co., Inc. 64s.)

In this Geneva presentation volume, Andrew Kramer traces the history of the boiling water reactor from the early steam slip experiments, through BORAX and the EBWR, to Dresden and the Humbolt Bay Plants.

Despite its apparent simplicity, the working of the BWR is complicated. Appropriately, the early chapters are devoted to a discussion of the principles underlying BWR operation and their effect on reactor design. A complete chapter is given up to an account of the BORAX experiments, which were of fundamental importance in the development of the BWR. The first experiments in this series demonstrated that the production of steam in a reactor core was not the calamity at one time supposed, but a process that could be used to make a reactor system operate stably, with a high degree of self-regulation. The later BORAX experiments provided grounds for supposing that the problems of radioactive carryover in the steam would be several orders of magnitude less than the pessimists predicted and suggested that a turbine could be directly coupled to a BWR without incurring problems of radioactive maintenance.

A description of the Argonne experimental boiling reactor and the experience of running it is given a prominent place in the book; a prominence which reflects the importance of the EBWR in boiling reactor development. Later chapters deal with the General Electric BWRs at Vallecitos and Dresden, with the Argonne Low Power Reactor, and with other less well-known projects such as the Allis-Chalmers Northern States Power Company's reactor (in which it is proposed to include provision for nuclear superheat), the Elk River and Humbolt Bay Plants that are to work in parallel with conventional plants and the Halden Reactor which uses heavy water and which is to supply process steam to a paper pulp plant. A final chapter mentions the SPERT experiments and speculates as to the place of the boiling water reactor in future power programmes.

The newcomer to whom this book is addressed, the engineer familiar with the principles of reactor technology but without special knowledge of the BWR, will consider that Kramer has been of great help to him. The literary reader will be puzzled by the variety of styles of writing. The engineer familiar with BWR technology will be able to supply the reason, for as he reads he will come upon word-for-word transcripts from earlier BWR writings. He, indeed, will find little that is new in this book, but he will find useful the excellent bibliographies that Kramer has provided.

H.W.B.

Chemistry for Engineers—An Introductory Course. By E. Cartmell, B.Sc. (172 pp., 72 illus. Butterworths Scientific Publications, 4 Bell Yard, London, W.C.2. 25s.)

To say that this book has an unusual approach is rather an understatement. The author, who is Lecturer in the Department of Chemistry at the University of Southampton, has used lectures given to first-year students, during the past seven years, as a basis for a background study not merely of chemistry but of chemistry in engineering, since, to quote his own words ". . . all engineers sooner or later become involved with chemistry, whether they like it or not."

In those last six words lies the stimulus for the book's existence. To a man reading for an engineering degree, chemistry—or, indeed, any subject whose immediate connection with the task in hand is not at once obvious—can be a dry and dreary chore. This is countered in the present work by making the connection obvious; by stating the theory in plain and simple terms, and immediately relating it to some problem of practical importance. Thus atoms, electrons, protons, neutrons, which open the book, are immediately linked with radioactivity, isotopes, nuclear energy and reactors. Atoms, molecules and bonds are linked with solid, liquid and gaseous states of matter; chemical reactions are linked up with internal-combustion engines, oil cracking and rocket fuels. Acids and bases are closely followed by corrosion protection and water treatment; macromolecular structures by plastics; friction and lubrication are not neglected. There are, in fact, two main themes; the chemistry of power production and the chemistry of materials, and each chapter has a useful bibliography for further study.

The book is ostensibly intended for those starting a degree or H.N.C. course. Many teachers of chemistry, however, will not find it unprofitable reading, while for older engineers who (like the present reviewer) learned their chemistry in the days when an atom was an atom, and a molecule was a molecule, and no nonsense about either, it will provide a painless method of alignment with up-to-date thought. J.A.B.-B.

Principles of Servomechanisms. By A. Tyers, A.M.Brit.I.R.E., and R. B. Miles, Grad. Brit.I.R.E. (176 pp., 190 illus., Pitman, 25s.)

Many younger engineers and students would like to study this subject, but are deterred by the mathematics which are inseparable from most text-book treatment. If they have some knowledge of elementary trigonometry, and the basic principles of electronic circuitry, they cannot do better than commence with this book, which manages to give a very clear idea of the general principles of system response without resorting to a single differential equation.

Subsequent chapters deal in a simple and practical manner with various servo components, including error detectors, synchro elements, modulators, valve and magnetic amplifiers, rate generators, rotating amplifiers, etc. There is a discussion on the relative merits of a.c. and d.c., a chapter on computers, and introduction to the circuitry of transistors. Additional reading is suggested for those who wish to pursue further a subject which is of ever-growing importance, and to which the present volume is an admirable introduction.

Books Received

Atomic Energy in the Soviet Union. By Arnold Kramish. Pp. 232. Oxford University Press, Amen House, Warwick Square, London, E.C.4. 27s. 6d.

"The Engineer" Buyers' Guide 1960. Pp. 976. 28 Essex Street, London, W.C.2. 7s. 6d.

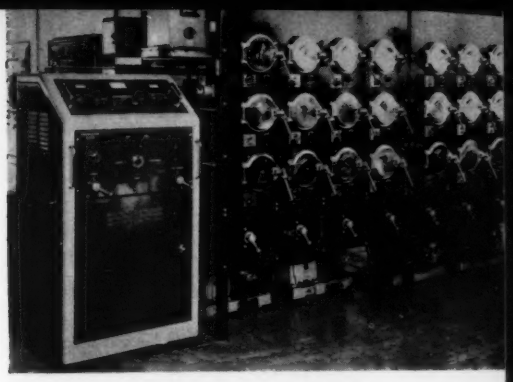
Zone Refining and Allied Techniques. By N. L. Parr. Pp. 184. George Newnes, Ltd., Tower House, Southampton Street, London, W.C.2. 40s.

Basic Data of Plasma Physics. By Sanborn C. Brown. Pp. 336. Chapman and Hall, Ltd., 37 Essex Street, London, W.C.2. 52s.

Atomic Radiation and Polymers. By A. Charlesby. Pergamon Press, Ltd., 4-5 Fitzroy Square, London, W.1. Pp. 556. 110s.

Processes and Equipment

For further information on any item please enter the relevant number on the Reader Service Card enclosed with this issue and forward the card to the address given.



The C.F.T.H. leak detector unit installed at Chinon for testing EDF1 fuel elements.

Production-line Mass Spectrometer

Flexibility in application, ease of operation and extreme sensitivity are amongst the good features of a mass-spectrometer-type leak detector unit, developed by the electronics division of the Compagnie Francaise Thomson-Houston, which is now available in this country.

The sensitivity of helium detection by a mass spectrometer is well known, and the performance of this particular instrument, the THM 105A, has recently been improved to the location and measurement of leaks as small as 10^{-12} cm³/sec., with rapid and simple operation.

The instrument, which employs 180° deflection, is contained, with its auxiliary gear and two-stage vacuum pumps (high-capacity mechanical for "rough" pumping and a silicone oil diffusion unit, capable of 10^{-6} mm Hg. for the "fine" stage) in a cubicle unit with control desk only 120 cm (3 ft 11¼ in.) high by 62 cm (24½ in.) wide by 60 cm (23¾ in.) deep, weighing 120 kg (265 lb).

The unit may be employed in several different ways; by applying a helium jet to the outside of a capsule under test; by a probe applied to the outside of a vessel containing helium under pressure, by the testing under vacuum of a capsule previously pressurized with helium. For production-line work, such as the routine testing of fuel elements, it is more convenient to provide a number of test chambers, arranged for rapid loading and unloading, and such an arrangement, installed for EDF1 at Chinon, is illustrated. Other installations are in operation at Marcoule.

(Leland Instruments, Ltd., 22 Millbank, London, S.W.1.)

1296

Glandless Pumps

Of Swiss design, manufactured by K. Rütschi of Brugg, the Perfecta range of canned pumps has been supplied for a variety of liquids, including freon, ammonia, acids, organic solvents, hot oil and radio-active solutions. Three main types are available. The simplest model utilizes stainless steel canning which is sealed by synthetic rubber gaskets, and can be used with all compatible liquids up to 100°C, and static heads up to 6 kg/cm² (85 p.s.i.). The Acid Perfecta, with a welded rotor sleeve, is constructed of 18Cr-8Ni-2.5Mo stainless steel

Cutaway view of Perfecta gasketed type canned pump.

(unless conditions indicate an alternative alloy) and has bearings of carbon, synthetic resin, stainless steel or p.t.f.e. An important feature for active work is the ability to remove the stator windings without emptying the pump. Operating limits are 130°C, and static heads of 10 kg/cm² (142 p.s.i.).

The third type, the Acitherm Perfecta, has a diaphragm between the motor and the pump, thus separating the liquid in the motor from the main flow. A secondary impeller provides closed circulation of this portion of the liquid, through the windings and a cooling coil in a water jacket around the motor stator, thus enabling the pump to be used up to 400°C without cooling the main flow of liquid. This type is suitable for static heads up to 50 kg/cm² (711 p.s.i.).

Standard sizes listed cover capacities ranging from 0.4—40 litres/sec (5.28—528 gal/min) and pressure heads of up to approximately 55 metres (180 ft), but larger sizes can be supplied. The smaller pumps are intended for direct insertion into a pipe line without necessity for offsetting, larger models are preferably vertically mounted on a bedplate. Submersible and self-priming ring types are also available.

(Mason and Morton, Ltd., Murray House, 3 Vandon Street, Buckingham Gate, London, S.W.1.)

1297

Dust Filter Plant

Advances in the efficiency of dust collection are expected from the Holmes-Retroflux bag filter manufactured under licence from the Standard Filterbau, G.m.b.H. of Munster. Much of the dust entering the filter bag is allowed to settle by gravity, the air velocity being kept low, and the design being such that the dust is not re-entrained by air currents, but the main feature is the continuous dislodgement of dust which has settled on the surface of the bag, without rapping or shaking. This is achieved by means of high-velocity air blown through the fabric in the opposite direction from jet tubes covering a portion of the periphery of the bag, shaped and finished so as not to damage the fabric, which travel slowly over the surface of the bag and dislodge the dust to hoppers or conveyors. The jets are mounted in frames; each pair of frames will clean up to 36 bags, in large installations.

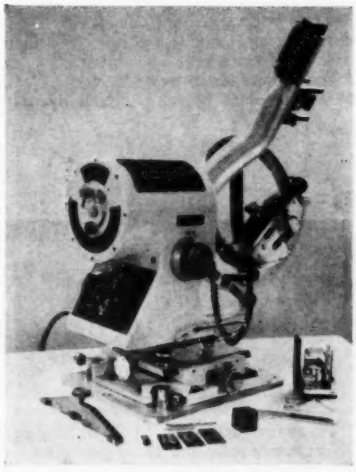
It is stated that by this means the pressure drop across the bag can be maintained at approximately one-half that of conventional bag filters, without sacrifice in filtration efficiency, or creasing or damaging the fabric.

(W. C. Holmes and Co., Ltd., Turnbridge, Huddersfield.)

1298

Multiplane Diffractometer

Based on a design in use at Harwell, a new X-ray crystallography unit uses the Shulz method of determining the preferred orientation of crystals, enabling the intensities of reflections to be related to the number of crystals reflecting. It can examine the structure of a specimen in any plane by simple adjustment of the goniometer ring. The counter arm and the ring are mounted on concentric bearings and scales give the angle to 1′ of arc. The



The "Secray" multiplane diffractometer unit.

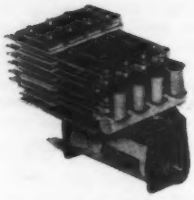
specimen holder can be rotated and reciprocated in the beam by two variable-speed motors.

Accessories include collimating slit system to bolt to Phillips X-ray tower, receptor, scatter, and Soller slits for counter arm, specimen gauges, and collet chucks for rod, sheet and tube specimens. An X-ray camera particularly suited to this instrument is under development.

(Seton Creaghe Engineering, Ltd., G. W. Trading Estate, Park Royal Road, London, N.W.10.)
1299

New Relay Designs

Two new Simmonds developments in the relay field may assist in some of the special problems which sometimes occur. First is a remanent relay, similar to the well-known P.O.3000, but fitted with a remanent core



The Simmonds Series 700 relay, for contractor duty.

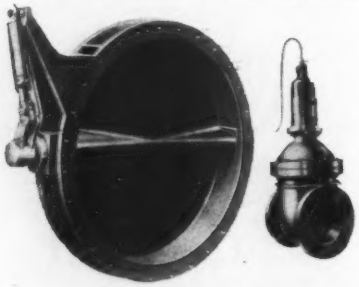
so that after energizing, the relay remains latched indefinitely—even under considerable shock and vibration—until released either by a pulse of opposite polarity, or by a pulse through a second operating coil. A wide range of contact arrangements is available, and special requirements are catered for.

The second relay, the series 700, is designed to fill the gap between the P.O.3000 and industrial contactors, and has already been adopted by the Admiralty. A maximum of 8 changeover contacts can be fitted, rated at 15A 250V or 5A at 440V a.c. Full tropical finish is standard.

(L. E. Simmonds, Ltd., 5 Byron Road, Harrow, Middlesex.)
1300

Valve Actuators

A new hydraulic or pneumatic actuator has been introduced by Hydraulics and Pneumatics, Ltd., a member of the Turner Manufacturing Group, for remote operation



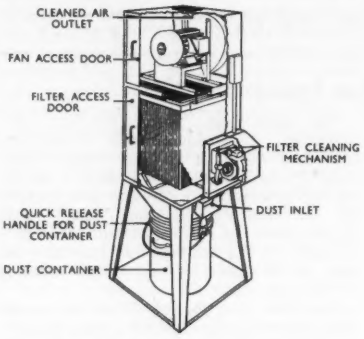
H. and P. actuators on 36 in. Boving butterfly valve and 12 in. gate valve.

of sluice, globe, or butterfly valves, giving either open-shut or positional control, holding the valve in any desired position without external lock valves. The actuator, in addition to being easily fitted, may be controlled by manual, hydraulic, pneumatic, or electrical means.

(Hydraulics and Pneumatics, Ltd., Wulfruna Works, Villiers Street, Wolverhampton.)
1301

Dust-collector Unit

Attractive features presented by the new Dallow Lambert "Unimaster" dust collector unit include compact design, an improved filter unit, push-button filter cleaning, quick-release sealing gear for the dust container, and, last but not least, flexibility of application, so that by selection of fans and filters, it is adaptable to large volumes of lightly contaminated air or small volumes of high burden.



The Dallow Lambert Unimaster dust-collecting unit.

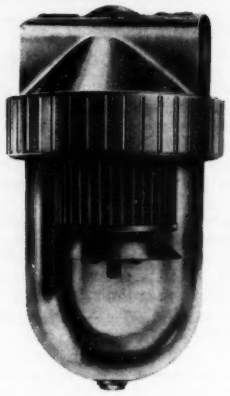
The motorized filter cleaning mechanism imparts, by means of an eccentric drive, an oscillating movement to the flexible mesh inserts, inside the filter pads, which form the heart of the "air-cushioned" elements. This rapid movement causes an air current in the reverse direction and, combined with the shaking, removes the accumulated dust on the filter surface. The cleaning mechanism is fitted with rubber self-aligning bearings, to reduce wear and maintenance to the minimum. If desired, a simple control gives automatic cleaning whenever the fan is shut down.

The new unit is available at the moment in the 70 series (70 ft² filter area) with fan capacity up to 765 ft³/min, but will shortly be available with filter area up to 250 ft².

(Dallow Lambert and Co., Ltd., Thurmaston, Leicester.)
1302

Pipe Line Filter

Two degrees of performance are obtainable with a new design of Vokes filter for small compressed air lines (¼, ⅜ and ½ in.). With shock-resistant plastics bowl for



Vokes compressed air filter.

pressures up to 150 p.s.i., and metal bowls above this pressure, filter elements can be either general-purpose type, where oil and water mists must be removed, but where concentrations are average, and the D-Pak type, where a higher degree of purity is required. The two types of filter element are interchangeable.

(Vokes Ltd., Henley Park, Guildford, Surrey.)
1303

BRIEFLY . . .

Ether Ltd., Tyburn Road, Birmingham 24, announce a new "Xactrol" potentiometer recording controller for on-off or anticipatory control. Suitable for temperature control from −200°C to 2,000°C, the instrument may also be applied to the measurement of speed, strain, pressure, hydrogen-ion concentration or any other quantity expressed by an electrical signal. **B.109**

A new range of control units for pneumatic or hydraulic installations comprising single and double pressure switches, relief valves and lamp annunciators is announced from **Firth Cleveland Instruments Ltd.,** Treforest, Glamorgan. **B.110**

A new cable racking system based on the Spur adjustable shelving system and capable of carrying the heaviest types of power cable has been announced by **Savage and Parsons Ltd.,** Watford, Herts. **B.111**

A sub-miniature thermal mercury relay, claimed to be one of the smallest in the world, has been developed by **Engel and Gibbs Ltd.,** of Warwick Road, Boreham Wood, Herts. With dimensions of 13/16 in. by 0.2 in. by 0.2 in. the relay weighs only 0.04 oz. **B.112**

Variable speed welding turntables of half-ton, one-ton and three-ton capacity and diameters of 24, 36 and 54 in. have been developed by **Courtburn Positioners Ltd.,** Kempston Hardwick, Bedford. **B.113**

Solenoid-operated automatic time delays, with mechanical escapements, are announced by **Electrical Remote Control Co. Ltd.,** Elremco Works, Harlow New Town, Essex. Time ranges available are 1-10, 3-30, 5-60 seconds or 1-5 minutes. **B.114**

Honeywell Controls Limited, Ruislip Road East, Greenford, Middlesex, have introduced a new bellows-type flowmeter featuring automatic temperature and static pressure stabilising. **B.115**

Honeywell Controls are also producing a new heavy duty valve actuator with capacitor motor and gear train. Available speeds range from 9 secs to 144 secs for 180° rotation. Maximum torque is 200 lb-in. **B.116**

Cockburns Limited, Cardonald, Glasgow, S.W.2, are now manufacturing under licence from Black Sivalls & Bryson, of Kansas City, the range of B.S. & B. pressure regulating equipment, including diaphragm-operated valves. **B.117**

Ultrasonic filter cleaning by the Pall-Cavitron HIPS (hyper intense proximal scanning system) is announced by **Aircraft Porous Media Inc.** a subsidiary of the Pall Corporation, 30 Sea Cliff Avenue, Glen Cove, New York. A concentrated beam of ultrasonic energy is focused on one small spot of the filter which is then revolved to cover the entire surface. **B.118**

A new miniature potentiometer produced by the Plessey Co. Ltd., Ilford, Essex, rated at 350 V, is only 0.5 in diameter. **B.119**

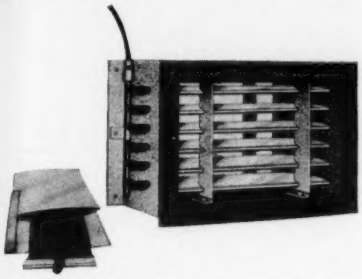
Electronic automatic control of metal spraying operations has been developed by Metallizing Equipment Company Ltd., Chobham, Woking. **B.200**

New silicon power transistors of the n-p-n- type and new germanium systems of the p-n-p type are announced by **RCA Gt. Britain Limited,** Lincoln Way, Sunbury-on-Thames, Middlesex. **B.121**

New miniature indicator lamp housings for situations where it is not desirable that either lamp or cover should be removable from the front of the panel are announced by **Electro Methods Ltd.,** Hitchin Street, Biggleswade, Bedfordshire. **B.122**

High-Velocity Air Valves

Positive control of large air volumes by a 15 p.s.i. auxiliary air line, without overloaded air motors or mechanical linkage, is the main feature of Ozonair's new "Pneumavalve" in which hollow vanes, expanding under the influence of an inflated neoprene actuator, throttle and eventually cut off the main air stream with minimum noise whilst



Ozonair "Pneumavalve." On left is an expanding vane with actuator.

throttling, and low pressure drop in the fully open position. Control of the actuators is by thermostat or pressure regulator.

Pneumavalves may be used for mixing, from hot and cold air ducts. Two valves are used, in a mixing box, the hot valve being controlled by thermostat; the cold, by constant-volume regulator.

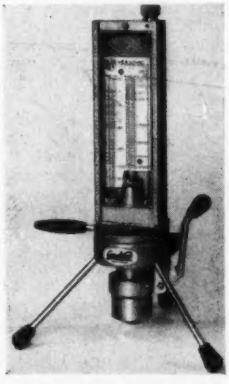
The valves are standardized in 16 sizes, from 10 x 6 in. to 32 x 24 in. (9,600 ft³/min) with dual duct mixing boxes in 9 sizes, from 1,500 to 9,600 ft³/min. A manually operated type is also available.

(Ozonair Engineering Co., Ltd., The Esplanade, Rochester, Kent.)

1304

Measuvac McLeod Gauge

A pressure range of 150 mm to 1μ Hg is obtainable with a new McLeod Gauge of small proportions and neat appearance. Two scales are provided, one reading from 1μ to 2 mm, the other 2 mm to 150 mm. The reading capillary tubes are completely



Measuvac McLeod gauge

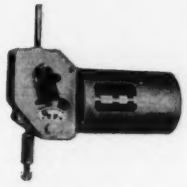
separate and easily detachable from the main body by knurled sealing glands. It is stated that, due to the reproducible accuracy between each gauge, replacement of scales, glasses, or bodies, may be made without calibration. Furthermore, the capillary tubes may be easily removed for cleaning.

(Genevac, Ltd., Pioneer Mills, Radcliffe, Lancashire.)

1305

Pipe-supporting System

The Bergen pipe-supporting system, well-known in the U.S., is now being manufactured under licence by W.M.G. (Guildford), Ltd. The system has been designed so that a range of standardized components will cater for all types of supporting problems, whether constant, variable, or rigid.



Bergen "Constant" pipe support.

Both types of spring support have many good features, including compact design, complete protection of mechanism against falling dust or debris during erection, and simplicity of installation. They are available in a very wide range of types and sizes.

(Alexander Cardew, Ltd., 2 Studio Place, Kinnerton Street, Knightsbridge, London, W.1.)

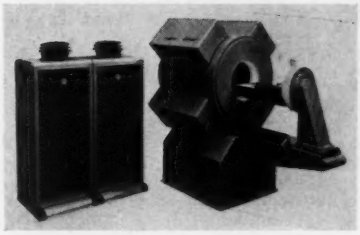
1306

Low-Level Counting Facility

Said to employ the largest plastic scintillator detector yet made, a new low-level counting facility has a motor-driven cradle which will take samples up to 2¾-in. diameter x 21¼ in. long. The sample is surrounded by at least 5 in. depth of NE 102 plastic scintillator, which is shielded by some 3½ in. aged lead. The scintillator is coated with high-performance diffuse reflector except where viewed by eight 5-in. E.M.I. type 9530 A photomultipliers.

(Nuclear Enterprises (G.B.), Ltd., Bankhead, Medway, Sighthill, Edinburgh, 11.)

1307



Nuclear Enterprises low-level counting facility.

Electronic Temperature Indicator

With a robust movement, operated by a simple servomechanism, the new Fielden-Bikini temperature indicator operates on the

Fielden-Bikini self-balancing temperature indicator.

self-balancing principle, utilizing a transistorized circuit in conjunction with resistance bulbs, and is available in several standard ranges, both Fahrenheit and Centigrade, within the normal limits of resistance thermometry (−200°C to +500°C) with an accuracy of 0.5% of range. The measuring circuit makes possible a distance up to 300 ft between the instrument and the measuring head, without affecting accuracy and, since the operating frequency is some 2,000 c/s, trouble due to mains-frequency pick-up on the leads is eliminated.

(Fielden Electronics, Ltd., Wythenshawe, Manchester.)

1308

CATALOGUES

"Forging in Magnesium Alloys" is a new publication from **High Duty Alloys Ltd.** In addition to several examples of intricate work—including, incidentally a fuel element spider of a nuclear reactor—the booklet gives complete technical data on Magnuminium 133, Magnuminium 133X (particularly suited to nuclear work), Magnuminium 266 and ZW3, a magnesium-zinc-zirconium alloy. (Slough, Buckinghamshire.)

The English Electric Valve Co. Ltd. has issued the 1960 edition of their abridged valve data, a quick-reference brochure for valve replacements and for all types manufactured including power rectifiers, thyrattons, klystrons, magnetrons, t.v. camera tubes, etc. (Chelmsford, Essex.)

A new catalogue, "Oil Retaining Bearings," has been issued by **Bound Brook Bearings Ltd.**, a member of the Birfield Group. It describes the general characteristics of the Lubrook and Ferrocite bronze and iron porous bearings and gives characteristics, standard limits and tolerances, insulation data and hints on machining. (Trent Valley Trading Estate, Lichfield, Staffs.)

Holmes Connersville cycloidal vacuum pumps are described, together with tables of sizes and capacities of single and two stage pumps, in a new publication No. 78 received from **W. C. Holmes & Co. Ltd.** (P.O. Box B.7, Turnbridge, Huddersfield.)

Londex Ltd. have issued their 1960 data book, a 48-page list giving particulars of all types of relays, timers, photoelectric counters, fluid and gas controls and miscellaneous equipment. Several new items are included, amongst them being miniature relays and two new models of their vane-operated airflow switches. (Anerley Works, 207 Anerley Road, London, S.E.20.)

Four new publications have been received from **Davidson & Co. Ltd.** covering "Siroccofin" gilled-tube air heaters, "Sirocco" contra-rotating axial flow fans, and "Three-B" propeller fans for moving large volumes of air against moderately low heads. The fourth, No. 534/59 covers sealed gas blowers, giving details of a typical shaft seal and illustrating the high temperature nitrogen blower for ZENITH and one capable of handling CO_2 at pressures up to 300 p.s.i. and temperatures up to 300° F. (Sirocco Engineering Works, Belfast, N. Ireland.)

Advance data sheets have been issued by **Ericsson Telephones Limited.** One (P 6002/1) describes the new miniature low-noise-level chopper relay, the other (P 6002/2) describes the G.P.S.T. miniature general-purpose relay, stated to be particularly useful for computer applications. (Beeston, Nottingham.)

Diaphragm seals for protection of pressure instruments against corrosion and clogging, by the interposition of a flexible diaphragm and inert filling, are described in a catalogue received from the **Brooks Rotameter Company.** (P.O. Box 432, Lansdale, Pennsylvania.)

Pipelines, civil engineering, cathodic protection, welding inspection, descaling cleaning and coating, are some of the items illustrated in a brochure describing the activities of the **William Press Group,** with an indication of some of the facilities available. (Willoughby Lane, Tottenham, London, N.17.)

The current issue of *Compressed Air Comments*, house journal of **Atlas Copco (Great Britain) Ltd.**, contains articles on compressed air in the operation of the Italian "Avogadro" swimming pool reactor, and in the testing of the containment shells of BR2 and BR3 at Mol. (Marylands Avenue, Hemel Hempstead, Herts.)

Patents Reviewed

These abstracts have been made from British Patent Specifications, complete copies of which can be obtained from the Patent Office, 25 Southampton Street, London, W.C.2, at 3s. 6d. each (including postage).

B.P. 818,777. Method of manufacturing water or hydrogen rich in deuterium. P. Harteck. To: Rensselaer Polytechnic Institute.

Deuterium is transferred from hydrogen sulphide to water in a first zone, from water to hydrogen in a second zone, in a cyclic system in which the water and hydrogen sulphide flow in counter-current. The first zone is kept at 40°C. In the second zone, the water contains an agent for lowering its freezing point to obtain a temperature difference of about 80°C. Deuterium enriched liquid is withdrawn from a point between the zones.

B.P. 818,779. Nuclear reactor. G. H. Haines, P. J. Grant. To: General Electric Co., Ltd.

This refers to a gas-cooled reactor in which the pressure vessel is constructed in the form of two shells, the inner shell forming a heat-resistant lining spaced from the outer shell. Cooling gas flows between the two shells. In order to restrict the upward flow of neutrons from the fuel elements to the upper part of the enclosing vessel, a protective shield is interposed inside the inner shell, designed as a sandwich with a material of high neutron capture cross-section (boron) between mild steel plates. The shield may be supported from the bottom of the control rod standpipes. The space about the shield is swept by cooling gas and as the shield covers effectively all the fuel elements it also reduces the temperature at the top of the pressure vessel.

B.P. 818,501. Valves for conduits carrying fluids. A. H. J. Thomas. To: U.K. Atomic Energy Authority.

The valve chamber has a number of ports with resilient valve seats. The valve member is laterally arranged on a swinging shaft which has its neutral position in the central axis of the box. In this position the valve member does not make contact with any of the valve seats. The shaft with the valve member is operated from outside to swing from the central axis into closing position towards one or the other of the ports. Leakage is eliminated by a sealing plate around the opening for the shaft in the box sliding over the wall of the chamber. The displacement of the shaft may be effected by screw jacks, and all operating mechanisms are outside the valve chamber, and thus free from possible contamination. This also facilitates repair and maintenance.

B.P. 819,521. Charge receptacles for ion source units. To: U.K. Atomic Energy Authority. (U.S.A.)

A receptacle of non-magnetic material with an outlet into a passage communicating with an arc chamber. The outlet closure of magnetic material is moved off the outlet by the calutron magnetic field. (Pat. appl. 1944.)

B.P. 819,561. Radiation detector. R. P. Aazzagatti. To: Texaco Development Corp.

A detector of the gas amplification pulse-producing type, for operation at high temperature, e.g., for well logging at above 300 to 350°F, has a housing formed of a plurality of stainless steel parts welded together. Anode and cathode may also be of stainless steel.

B.P. 819,762. System for extracting heat from gas-cooled nuclear reactors. To: Commissariat à l'Energie Atomique. (France.)

The coolant gas in such reactors is circulated by a compressor and the problem arises how to prevent radioactive coolant gas passing along the driving shaft into the atmosphere. The problem has been solved by surrounding the rotating parts of a gas turbine and a gas compressor, whose rotors are rigidly connected, by a casing rigid with the stators of turbine and compressor.

B.P. 819,825. Heat exchangers. To: Stein and Roubaix. (France.)

This refers to heat transfer from a first fluid to a second fluid by an intermediate third fluid because direct contact between the first and the second fluid may be dangerous. The pressure of the intermediate fluid is controlled in such a manner that it may serve for detecting leaks. The known arrangements include bellows or expansion joints which are intricate and expensive and pose problems due to the high pressure and high thermal stresses. They can be dispensed with by making the heat exchanger of straight and curved parts (hairpin bends). The straight parts consist of internal tubes for the fluid to be heated closely surrounded by tubes carrying the intermediate fluid. The curved parts of the internal tubes have the same diameter as the straight parts but the surrounding tubes are of greater diameter so that the curved internal parts may expand freely within the bend. The external tube assembly containing the heating fluid surrounds only the straight parts of the intermediate (and internal) tube assembly, the external tubes directly communicating with each other. A very high heat-exchanging coefficient is obtained in extremely compact units. The heating fluid may be molten sodium, the intermediate fluid mercury.

B.P. 819,966. Lifting devices particularly for use with nuclear reactors. E. E. Jenkins, D. J. Dawson. To: U.K. Atomic Energy Authority.

The device is intended for picking up a fuel element from the bottom of a vertical channel. The device is suspended from a winch by a cable containing a pipe leading to a bellows in the elongated body of the device. The bellows is expanded by carbon dioxide moving a push rod and an actuator in the body, operating the gripping hooks. The device is lowered into the channel until the mouthpiece touches the fuel element, electric contacts closing a circuit to indicate to an operator that the device has landed. The closure of the contacts also causes unlocking of the gas valve venting the bellows, the push rod retracts and the hooks engage with the fins of the fuel element. The lifting device can now be raised by the cable. When the fuel element is deposited on a support the weight of the lifting device again closes contacts causing the gas valve to pressurize the bellows which expand and move the push rod to disengage the hooks.

B.P. 820,037. Supporting means for pressure vessels. R. Hicks. To: Simon-Carves Ltd.

Bending and shear stresses and local distortions are kept very low by axially slotting the part of the supporting skirt which is attached to the vessel so as to reduce its resistance to bending by movements and shear forces. In the case of a vessel seated on top of the skirt, the length of the slots must be kept within reasonable limits so that the unslotted part is safe against buckling. The design is also applicable for the suspension of a skirt from an overhead anchorage.

B.P. 820,219. Nuclear reactors. W. E. Dennis. To: General Electric Co., Ltd.

Common material for control rods is boron steel but it is difficult to form by casting and it melts at a comparatively low temperature (about 1,400°C). A cheap and light control rod, unaffected by a high reactor temperature, is made of a carbon body, containing at least one element having a high neutron capture cross-section (boron, but also cadmium, gadolinium or their carbides). The boron percentage may be 10-20%. For manufacturing, the Delanium process may be used as described in B.P. 595,759.

B.P. 820,441. Method and device for the measurement of ionizing radiation. To: Aktiebolaget Sivo. (Sweden.)

The invention is based on the so-called condenser-chamber method in which the chamber charged to a certain potential during the radiation is completely separated from the voltmeter. Only after it has been charged is the voltmeter applied to the chamber. In order to use the method for large and heavy chambers, the operation is divided into two steps. In the first step a potential is applied between the housing of the chamber and an insulated bushing surrounding the test electrode so that the housing is kept continuously at a constant negative potential with respect to the bushing. The grid of an electron tube is first connected with the test electrode and the housing and, at the same time, a certain voltage of constant negative value with respect to one pole of the tube is applied to the grid. Thereafter the tube is disconnected from the isolated bushing during a time corresponding to the test period. In a second step the grid of the tube and its surrounding shielding casing is inserted in the isolated bushing in a position out of contact with the test electrode while the reference potential is impressed on the grid, after which a projecting grid pin is brought into direct contact with the test electrode. The change caused in the anode current is then compensated by a control electrode by adjustment to a potential indicative of the quantity of radiation.

B.P. 820,466. Nuclear steam generator. To: Babcock and Wilcox Co. (U.S.A.)

A pressure vessel is divided into an upper steam chamber with a steam outlet and a lower fission chamber containing water-cooled and moderated fissile fuel. The generated steam is mechanically separated from the steam-water mixture coming from the fission chamber and the separated water is passed back to the fission chamber by a positive circulation flow system.